An alternative climate change levy scheme for manufacturing industries

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An Alternative Climate Change Levy Scheme for Manufacturing Industries

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Abstract

The threat of global warming from an enhanced greenhouse effect caused by increased levels of greenhouse gases in the earth's upper atmosphere, could be one of the biggest concerns for international governments for the foreseeable future. The threat has led to the commitment of most developed countries, with the notable exception of the USA, to reduce their emissions of these gases in an attempt to stabilise atmospheric concentrations. Under an agreement reached at a United Nations Conference on Climate Change held in 1997 in Kyoto, Japan, (the Kyoto Protocol), the United Kingdom government has pledged to reduce greenhouse gas emissions by 8% below 1990 levels for 2008-2012, and additionally committed to reduce emissions of carbon dioxide by 20 per cent below 1990 levels by 2010.

As the combustion of fossil fuels is the greatest source of CO_2 emissions, reducing their use is an important step for meeting the targets. To encourage lower energy use by business, a climate change levy is being applied to business energy. The levy will increase industry's energy costs but to mitigate its adverse competitive effects in energy intensive sectors, a levy discount scheme is available. However, since in its existing form, many firms do not qualify, the scheme will be costly to administer, many firms have not taken up the discount, and it will be burdensome for those that have.

Like many of the energy intensive industries, the aluminium casting sector is under severe global competitive pressure and needs to reduce specific energy consumption to meet its sector target. This must be achieved without increasing production costs.

The aims of the research was to find the specific energy consumption of aluminium casting processes and identify the scope for energy saving. In order to achieve these aims, the research investigated the aluminium casting sector of the foundry industry through the use of structured interviews with foundry managers, a questionnaire, and case studies. The data from these sources was then used as the basis for the construction of an alternative incremental levy scheme. Building and running a model using the research data with various levy rates and modes of application then tested this alternative strategy.

As a result, it was possible to draw three major conclusions. First, that the sector could meet its energy reduction targets set by the government. Second, an incrementally applied levy, (without reduced National Insurance contributions as now), could drive energy efficiency without raising costs. Third, an incremental levy would encourage energy efficiency in all business sectors.

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Glossary of abbreviations

ALFED	The Aluminium Federation
ACE	All cost effective
ATP	All technically possible
BAU	Business as usual
BMCA	British Metal Casting Association
CMF	Cast Metals Federation
DTI	Department of Trade and Industry
DETR	Department of the Environment, Transport and Regions
DEFRA	Department for Environment, Food and Rural Affairs
EMS	Energy Management System
ETBPP	Environmental Technology Best Practice Programme
ETSU	Environmental Technology Support Unit
EU	European Union
IPCC	Intergovernmental Panel for Climate Change
IPPC	Integrated Pollution Prevention & Control Directive
OFGEM	Office of Gas and Electricity Markets
PPC	Pollution Prevention and Control Regulations 2000 (PPC)
SEC	Specific energy consumption
SIC	Standard Industrial Classification
SME	Small and medium sized enterprise
kWh	Kilowatt-hour
kWh_e	Kilowatt-hour of effective energy
kWh_p	Kilowatt-hour of primary energy
MWh	Megawatt-hour
GWh	Gigawatt-hour
TWh	Terawatt-hour
MJ	Megajoule
GJ	Gigajoule
TJ	Terajoule
LPG	Liquefied petroleum gas
UK	United Kingdom

Chapter 1: The Global Warming Issue

1.1 Introduction – The problem

The threat of global warming caused by increased levels of 'greenhouse' gases in the atmosphere is emerging as one of the most pressing concerns for the international community of nations and has been adopted by the United Nations at a series of meetings and conferences. One of the most important of these was held in Kyoto, Japan, when representatives of the 160 nation states attending signed a protocol and in doing so agreed that developed countries are collectively committed to reduce their emission of greenhouse gases by an aggregate of 5.2% compared to 1990 levels by the period 2008 - 2012. Prominent among the nations signing the Kyoto protocol were the member states of the European Union which, together with certain other developed nations, have taken a leading role in the problematization of the issue. As a member of the EU and a signatory to the protocol, the United Kingdom government agreed to reduce greenhouse gas emissions by 12½% below 1990 levels by 2008-2012. Since carbon dioxide (CO_2) is the most important of these gases, the government has additionally made a unilateral commitment to reduce specifically CO_2 emissions by 20% below 1990 levels by 2010. As the combustion of fossil fuels is the greatest source of carbon emissions, reducing their use is the most important step for meeting the targets.

The government expects all sectors of the economy to contribute to its carbon reduction strategy and has introduced both industry-specific and general measures to encourage participation. Economic instruments in the form of taxes and fuel duties, and the regulation of vehicle emissions have been used to encourage fuel efficiency in the transport sector. The government's policy for the electricity generating industry to switch from coal to gas led to a large reduction of carbon emissions.

To encourage lower energy use by business, the government has introduced the climate change levy (CCL). This operates as a fixed charge per kilowatt-hour of energy. It is not a tax because the levy is not linked to price paid. However, if the operation of the levy adversely affects the international competitiveness of the UK's energy intensive industries, it could lead to their closure. Should this occur, the risk is that the products of these industries could be made in countries where there are no restrictions or economic penalties for inefficient energy use. Therefore the use of economic instruments such as the CCL to encourage reduced industrial must:

- not reduce competitiveness;
- preserve the manufacturing capability of the UK (including its energy intensive industries);
- not lead to CO_2 emissions being exported to unregulated countries resulting from the closure of UK facilities.

The levy works by adding set charges (levies) to energy suppliers' bills to users. The aim was to force companies to look at ways in which they could produce energy savings by threatening their competitiveness and profitability. These adverse effects of the CCL would potentially fall most heavily on energy intensive industries.

The most energy intensive industries are power generation, iron and steel, paper and pulp, cement, chemicals and non-ferrous metals. When the proposal for a levy on business energy use was announced, there were many objections from these sectors in particular, and trade associations in general. Most of the objectors claimed that it would be impossible to make energy improvements that would mitigate the cost impacts of the levy and that the levy would reduce international competitiveness.

As a result of the objections, the government offered levy discounts for energy intensive sectors that accept energy reduction targets. Prominent amongst these was the foundry sector, which was faced with several important issues. Discounts are only available for firms that qualified either as being covered by the EU Integrated Pollution Prevention & Control Directive (IPPC), enacted in the UK in the Pollution Prevention and Control Regulations 2000 (PPC) and those processes deemed by DETR to be technically linked. Non-PPC affected companies may adopt sector targets for the duration of the agreement or convert to a site specific target by commissioning an independent energy audit at any time up to July 2002. This is seen as unfair by some firms that are not PPC regulated and cannot justify the costs of joining a sectoral arrangement. Those that signed to discount schemes must install measures to monitor and manage energy use, and be able to provide evidence that site specific targets have been met.

The specific energy reduction target set by the Energy Technology Support Unit (ETSU) for the foundry sector is 11% below baselines set at either 1998 or 1999 – whichever is most favourable for individual sites. The levy discount scheme is complicated and will be expensive for firms to administer – further adding to production costs. In some cases, it is likely that the cost of administration and metering will be greater than the discount.

The problems are – the government must meet its commitments, and industries must reduce their specific energy consumption (SEC) to offset the cost of the climate change levy (CCL). The levy in its present form is a complicated tool. The hypothesis for an alternative mechanism for applying the levy is discussed in Chapter 5. If the alternative proposed here is adopted, it could reduce the possibility of adverse effects on the competitiveness of business in general, and energy intensive industries in particular.

In summary, the problem is that for the government to meet its commitments, industry must reduce its energy consumption, but must avoid the cost-increasing burden of the CCL. This dilemma was the core problem addressed by the research reported here. The work that has been undertaken focused on aluminium foundries. Four surveys were undertaken on three foundry sites. The aims were to undertake a detailed investigation into the energy used in each of the casting processes used in the foundries and to explore the potential ways that energy could be saved to offset the cost of levies. Research into energy use by aluminium foundries showed that the amount of energy used for melting and holding varied widely for each casting process.

The host foundries granted free access. The use of energy in foundry processes was investigated by installing meters on furnaces and recording gas and electricity used for melting and holding metal in the liquid state. Data was recorded by taking regular energy meter readings and weight of metal melted and cast. Allowances were made for material losses from the system. The data was collated and opportunities for energy savings formulated. The research provided conclusions on which to base a scheme of incremental levies as an alternative to the government's present climate change levy scheme.

This chapter sets out the background and context of research into the problem of reducing the SEC of UK industries without impairing their international competitiveness. It discusses the climatic and other changes that have prompted rising international concern, and the way in which these have resulted in political pressures to address the global warming issue.

The first section deals with the phenomenon and dynamic climate mechanisms of the greenhouse effect and global warming; and discusses the debate concerning whether global warming is actually taking place. This is followed by the second section which traces the development of global warming as an international issue. The attitudes to environmental matters are then examined, and links with ethics established.

The UK government's commitments are then explained in detail since these form the starting point for the research that has been undertaken. Finally, the remainder of the thesis is outlined.

1.2 Global warming and the greenhouse effect

The argument for the existence of global warming due to increasing levels of greenhouse gases in the upper atmosphere mainly arising from energy use, is only one outcome of anthropogenic pollution of the earth's eco-system. However, global warming may be one of the most significant, and yet could be one of the easier to control.

Increasing energy use results from:

- population growth;
- industrialisation and economic development of emerging nations;
- demand for better living standards for today's populations and presumably the expectations of future generations.

Control of these factors is not feasible nor desirable, therefore the argument is that actions need to be taken in an internationally co-ordinated fashion to reduce the concomitant use of energy and so alleviate the potential impact of energy related emissions on the global climate. In the following five sections, the mechanisms that lead to increased global warming and the risk of climate change will be discussed in detail.

1.2.1 The mechanisms involved

The greenhouse effect

Without the phenomenon of the greenhouse effect, earth life as we know it could not exist. Global temperatures would be much lower than they are – perhaps only averaging minus 17°C compared with the existing average temperature of plus 15°C. There is evidence to suggest that the greenhouse effect has fluctuated considerably in the past, but present concern is due to its increasing intensity and the associated global warming that may result.

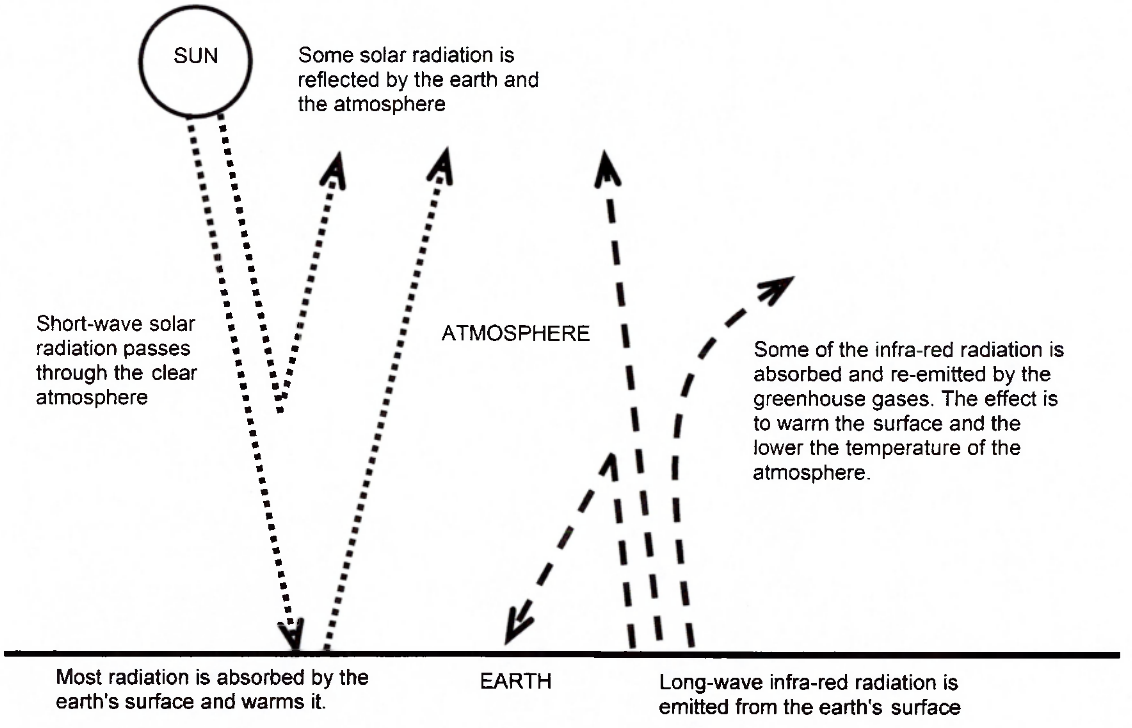


Figure 1.1. ***Schematic diagram illustrating the greenhouse effect.***
(Source: Houghton *et al.*, 1990)

The greenhouse effect is caused by heat generated by infrared radiation from the sun becoming trapped in and by the earth's atmosphere. Figure 1.1 illustrates the natural greenhouse effect whereby short-wave solar radiation passes through the clear atmosphere. Long-wave infrared radiation emitted by the warm surface of the earth is absorbed partially and re-emitted by greenhouse gases (GHG) some of which, such as water vapour, carbon dioxide, ozone, and other trace gases, are naturally occurring. In its natural state of balance, the average outgoing radiation balances the incoming solar radiation. The process occurs naturally and is critical to sustaining life on the planet. The principal greenhouse gases that are attributable to *human* activity are CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. These gases absorb outgoing infrared radiation, and their increase may cause abnormal variability in climate and weather patterns.

Some GHGs are increasing as a direct result of man-made emissions. Human activities that raise atmospheric concentrations of greenhouse gases include industrial processes from which the gases are a by-product of energy used. Examples are metallurgical and chemical processes, electricity generation from hydrocarbon sources, especially coal; and use of internal combustion engines for transport. The most important of these are CO_2, methane, and chlorofluorocarbons (CFCs). The main source of 'new' CO_2 is from the combustion of fossil fuels.

Of the world's total CO_2 emissions, only a small fraction result from the activity of humans, but it is this fraction that might threaten the equilibrium of the earth's finely balanced eco-system. The world's population is growing by 100 million per year and the expectation of prosperity is spreading. Both of these factors will increase the demand for energy and the consequent associated emissions.

The main naturally occurring greenhouse gas in the atmosphere is water vapour. But water vapour is less important in the context of global warming since the natural recycling of water through the hydrological cycle ensures that its atmospheric concentration is not significantly influenced by human activities.

All greenhouse gas concentrations are determined by a balance between sources (processes that produce GHGs) and sinks (processes that remove GHGs). There are two ways that mankind increases the concentrations of GHGs: by increasing emissions, and by decreasing the strength of the sinks.

Carbon dioxide is the most abundant of the greenhouse gases in the upper atmosphere and contributes to 80% of the greenhouse effect. CO_2, like some other greenhouse gases, contains carbon – one of the most common elements in the eco-system. The carbon in the system is 'mobile', readily changing its affiliation with other elements in response to biological, chemical and physical processes. This mobility is controlled through a natural 'bio-geochemical' cycle that maintains a balance between the release of carbon compounds from their sources and their absorption in 'sinks'. The natural cycle is self-regulating, but with a time scale in the order of thousands of years. Kemp (1994) observes that over shorter periods the cycle appears to be unbalanced and supports the suggestion that this may indicate an incomplete understanding of the process of regulation, or perhaps the presence of sinks or reservoirs as yet undiscovered. Once the CO_2 concentration in the atmosphere has increased, it remains stable and takes about 100 years for the concentration to reduce *even if no more CO_2 is added.*

About 20 billion tons of CO_2 are released to the atmosphere per year, (Bolin, 1970:131). But Meadows et al., (1972) suggest that only about one half of the CO_2 released from burning fossil fuels had appeared in the atmosphere by 1970. The other half is assumed to have been absorbed, mainly by surface water of the oceans. The sea responds only slowly to changes in atmospheric CO_2 levels. It is thought that this may explain the apparent inability of the oceans to absorb more than 40-50% of the CO_2 added to the atmosphere by human activities – even though they have the capacity to absorb more.

Carbon emissions are measured in gigatonnes and concentrations in parts per million (ppm) in the atmosphere. The atmospheric concentration of CO_2 observed since 1958 at Mauna Loa, Hawaii has increased steadily by an average of 1.5 ppm a year. Robinson *et al.,* (1998) estimated that each year the exchanges are: 90 GtC between the atmosphere and the surface ocean; 60 GtC atmosphere and vegetation; 50 GtC surface ocean and marine biota; and 100 GtC between the surface ocean and the intermediate and deep oceans. Using the *known* exchanges of CO_2 between atmosphere, biosphere and oceans, Machta (1971) predicted that the CO_2 concentration would reach 380 ppm by the year 2000. This would be an increase of nearly 30% of the probable value in 1980 and about 100 ppm higher than pre-industrial levels. Machta suggests that the source of this exponential increase in atmospheric CO_2 is the increasing combustion of fossil fuels, which adds more than 5.5 billion tonnes of CO_2 to the atmosphere every year.

Photosynthesis

Another important and related sink is photosynthesis by vegetation on land, and plankton in the sea. Most of the CO_2 absorbed by photosynthesis, is however released again when plants and plankton decay or are eaten by animals. Therefore, only a small net fraction is removed by photosynthesis.

Photosynthesis is the process through which flora convert solar energy into chemical energy. Figure 1.2 illustrates the process whereby there is a gaseous exchange as CO_2 is taken into the plant leaves and broken down into carbon and oxygen – the oxygen being released into the atmosphere. The carbon combines with hydrogen from the moisture in the soil to form carbohydrates.

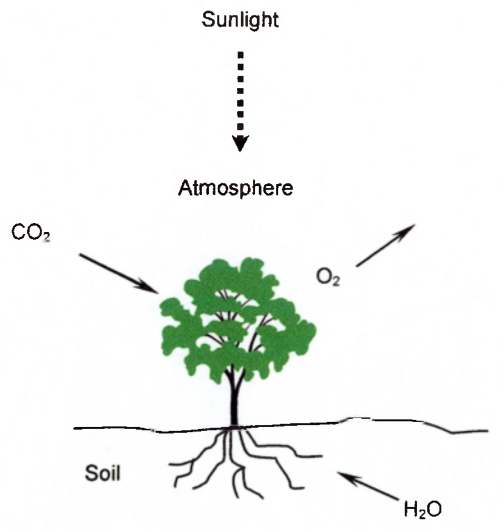


Figure 1.2. ***Diagrammatic representation of carbon exchange due to photosynthesis.***

Although the growth of plants removes carbon dioxide from the atmosphere, some agricultural operations – such as paddy rice growing and feedlot-based farming, add significant amounts of methane, an important greenhouse gas, to the atmosphere. As industrial and these types of agricultural activities are essential for developed economies, actions that attempt to reduce GHG emissions substantially have significant economic implications. The rapidly growing economies of Asia and Latin America, as well as increasing agricultural output, are increasing their greenhouse gas emissions as by-products of their industrial transformation.

Kemp (1994) quotes the estimation of Waterstone (1993) that deforestation is responsible for 5 - 20% of anthropogenic CO_2 emissions. Between 1850 and 1950, 120 billion tonnes of carbon were released into the atmosphere as a result of deforestation and the destruction of vegetation by fire. (Stuiver, 1987). In contrast, the burning of fossil fuels produced only half that much CO_2 over the same period. The destruction of natural vegetation not only contributes to the increased CO_2 burden in the atmosphere, but also reduces the capacity of one of the natural sinks through photosynthesis. Citing Moore and Bolin (1986), Kemp states that current estimates indicate that the atmospheric CO_2 resulting from reduced photosynthesis and clearing vegetation is equivalent to about 1 billion tonnes per year.

The atmosphere holds more than 750 billion tonnes of CO_2, 2000 billion tonnes are stored on land, and almost 40 000 billion tonnes are contained in the oceans. A further 450 to 600 billion tonnes of carbon is embodied in living organic matter. The reserves of fossil fuels account for some 5,000 billion tonnes of stored carbon that has been inactive for millions of years.

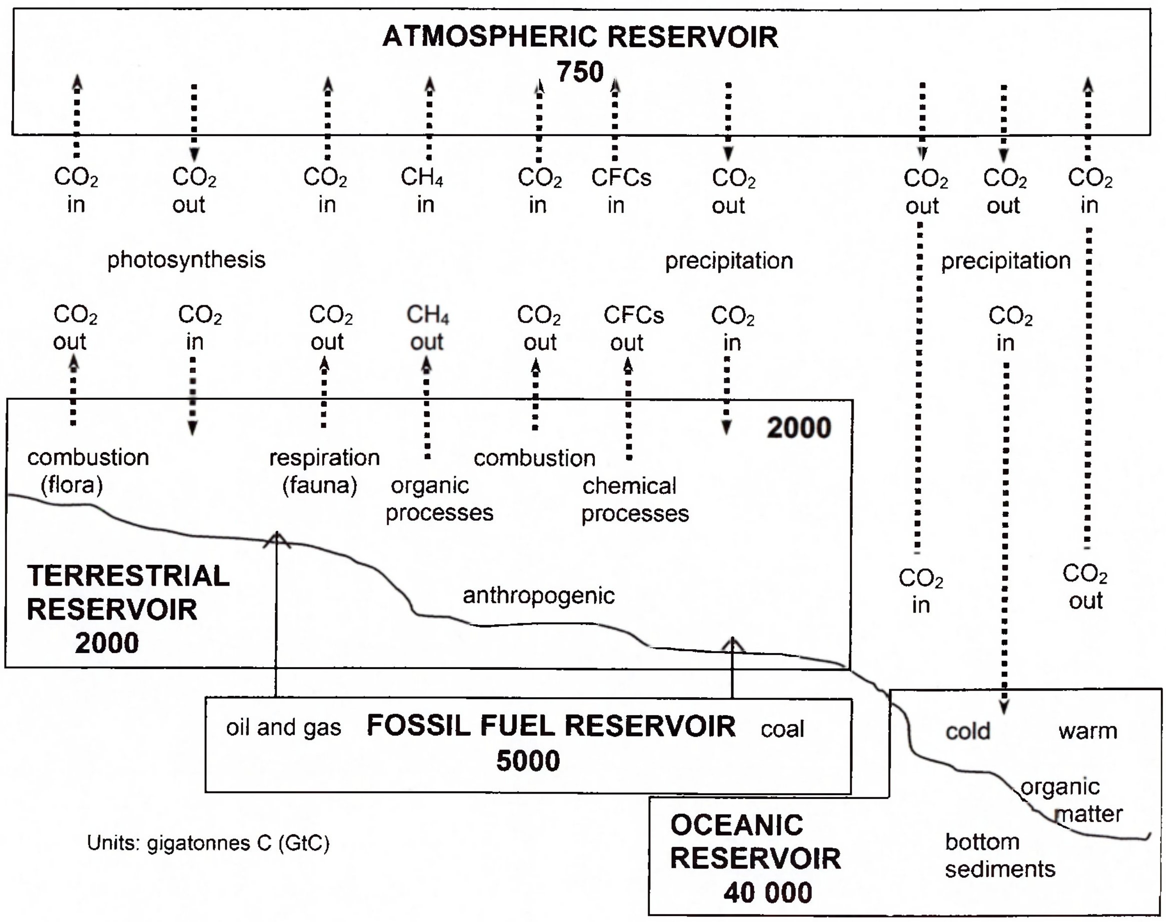


Figure 1.3. ***Schematic representation of the storage and flow of carbon in the earth/atmosphere system.*** Source: Kemp (1994)

Houghton (1998) observes that it took one million years to lay down the fossil fuels that are now used in one year. It is the rapid extraction of, and the subsequent combustion of

these fossil fuels that may create an imbalance of the earth's otherwise relatively stable carbon system when carbon is released into the atmosphere as carbon dioxide.
It is not only the combustion of fossil fuels for manufacturing, power generation and transport that has caused the increase, some of the increase must be attributed to other anthropogenic sources of which one of the most significant may be deforestation though its effect is more difficult to quantify.

Deforestation and the clearing of vegetation have a profound impact on the earth's carbon system through four mechanisms:

- the capacity for photosynthesis is reduced;
- CO_2 is released when the vegetation is burned;
- CO_2 is released by the decay of the biomass;
- the increased rate of oxidation from the newly exposed soil.

The clearing of vegetation raises CO_2 level indirectly through reduced photosynthesis and therefore exacerbates the enhanced greenhouse effect; but CO_2 is also added directly to the atmosphere by burning and decay of biomass, and by the increased rate of oxidation from newly exposed soil.

Although the principal natural fluxes of carbon between the earth's atmosphere and biomass, and between the atmosphere and the oceans vary, they have no long-term impact on the greenhouse effect, as they are an integral part of the eco-system in equilibrium. However, inputs from the combustion of fossil fuels, although smaller than the natural flows, involve the reintroduction of carbon that has been inactive for millions of years. The natural sinks may be unable to cope with the additional CO_2 as rapidly as it is being introduced, and the excess remains in the atmosphere. This could intensify the greenhouse effect and exacerbate global warming.

Current "business as usual" projections suggest that CO_2 levels are likely to double from pre-industrial levels by the middle of the next century. This increase will result in an estimated increase in global mean surface temperature in the range of 1.5 - 4.5°C by 2100. (NERC, 1998)

1.2.2 The global warming debate

Global warming may be defined as a rising average mean surface temperature of the earth, the slight increase of which could damage plant and animal species because biological adaptation to environmental changes occur very slowly. The greenhouse effect is not a modern phenomenon; it has been a variable characteristic of the earth's atmosphere for millions of years. Scientific climate studies indicate that increased concentrations of greenhouse gases, within the earth's atmosphere may cause an *enhanced* greenhouse effect. (UNEP, 1993 & 1998), (5EAP, 1998), (IPCC, 1996).

There is growing concern about two facts – the concentration of carbon dioxide in the atmosphere is rising, and the earth's surface temperature is increasing. Science is open to refutation, amendment and development but a consensus among the world's leading scientists and well informed people outside the scientific community consider that there is a discernible human influence on climate and a link between the concentration of carbon dioxide and the increase in temperature.

There has always been some GHG emissions from human activities, but this increases with population growth and economic development. At the same time the carbon sinks are reduced by de-forestation. Without industrialisation, but with an exponential growth in population, it is possible that even then there would have been a risk of global warming albeit much more slowly, allowing adjustments to occur to maintain a balance. On the other hand, if the rate was very slow, the change might not be detected until it would be impossible to take effective actions to reverse the trend. This is a hypothetical argument with so many factors to consider that it can only be a point for debate on the general topic of global warming. The natural phenomena of global atmospheric, oceanic and ground temperatures, and the influences and interactions with the earth's natural heating and cooling system are complex. Therefore, the potentially profound impact on the earth's ecological stability must be treated seriously.

Cline (1992a) emphasizes that, in the absence of policy intervention, global warming is likely to extend far beyond the amount associated with a doubling of pre-industrial atmospheric concentrations of carbon dioxide which could occur as early as 2025 (IPCC, 1990). Other scientists (for example, Houghton, 1997) argue that a degree of climate change as a result of global warming is inevitable and that it is too late to stop. If this is the case, the only course open is to adapt to the change. In the short term, this may be feasible for some developed countries, particularly where the direct impacts will be relatively minor. However, poorer countries – especially those in which the consequential impacts could be severe droughts and floods – will be unable to meet the financial burden of adaptation to climate change.

There are dissenters with strong arguments against the theories and models of climate change caused by increasing levels of greenhouse gases mainly from anthropogenic sources. Sceptics claim that those changes that have occurred recently are not extraordinary – that the earth's eco-system has adapted in the past and can adapt in the future to the effects of human activities without calamitous effects on its populations.

The validity of climate change models is questioned by some scientists. Klein (1997) for example lists some of the possible sources of errors such as:

- estimations of the rate and volume of emissions from prevailing technologies;
- reactions of consumers and producers to price changes, either by market forces or by tax changes on the use of energy;
- a flawed global database, such that some magnitudes are not available and the combustion effects, on a global basis, from the burning of fuel are not precisely known;
- effects of climate and other natural conditions in which the model is assumed to operate not being fully known.

Some scientists believe that the apparent rate of global warming is not occurring as rapidly as was first thought. There are various reasons why this may be so. One is that that the increased combustion of fossil fuels has increased the emissions of all pollutants including acid rain. The latter is thought by some scientists to have reduced the migration of CO_2 to the upper atmosphere where it enhances the greenhouse effect.

Climate scientists do not agree on many key issues, including *when* human induced climate change is likely to be detected. Furthermore, there is significant uncertainty in the scientific and analytical communities about the extent, causes and implications of global warming.

Is there incontrovertible evidence that global warming or the currently observed climate change is due to added greenhouse gases from human activities? If so, can the eco-system adapt to cope with the extra burdens that allegedly are the cause? These questions cannot answered definitely and there is a very broad debate on the issues involved.

Greenhouse gas emissions from anthropogenic sources are not the only factors affecting global temperatures. There are other factors also linked to human activity; for example industrial emissions of sulphur dioxide may have a cooling effect. Other cooling effects are natural such as volcanic eruptions (which can cool the climate temporarily), and variations in the energy output of the sun (sunspot activity). Natural climate variations make it difficult to recognize long-term trends but statistics (UNEP, 1993) indicate a global warming of 0.45°C since the beginning of the 20th century, but substantial fluctuations have occurred around this underlying trend.

Aerosols such as sulphates released during combustion of fossil fuels may slow the warming effect of CO_2 by reflecting sunlight away from the Earth. (Rind, 1998:1152) However, since sulphates are easier to limit than CO_2, controlling their emissions for health reasons may exacerbate warming.

Even if it cannot be proved conclusively that CO_2 emissions from the combustion of fossil fuels are causing adverse climatic changes, conservation of fossil fuels for sustainable development is a very sound reason for action. There is a strong macro-economic case for more prudent consumption of indigenous fossil fuels – particularly the cleaner energy resources of natural gas and to a lesser degree – oil. Reducing the rate of use of fossil fuels would contribute to sustainable development and it makes sound economic sense. However, continuing use at the present rate also will drive the development of alternative technologies.

The possible link between increased greenhouse gas emissions and climate change should not be ignored. If humankind is to take responsibility for the planet, then it will be necessary to take precautionary action as soon as possible. Although climate studies may be questioned for the reliability of their data and the bases of the models used, most climatatologists believe that the climate will warm by at least 2.0°C over the next century. The international community has accepted the fact that in order to avert adverse climatic changes, the emissions of greenhouse gases must be reduced. The principal anthropogenic greenhouse gas is carbon dioxide, and member states of the United Nations have agreed actions to reduce its production and that of the other GHGs.

The next two sections will deal with the arguments for and against the global warming theory, but whichever way the argument is seen, there are other valid reasons for developed countries to take action now to reduce energy consumption in general and fossil fuel use in particular. In the UK and other EU states there is an opportunity to create a new energy balance that would lead the world. For example, by using renewable sources and nuclear power, and setting high efficiency standards for energy using goods and processes, there would be no need to enforce energy use reduction.

1.2.3 Scientific evidence of global warming

The greenhouse effect was first recognized by the French mathematician Joseph Fourier in 1827 (Hutchinson Encyclopaedia, 1996), but it was not until 1905 that the Swedish scientist, Svante Arrhenius predicted that an increase in CO_2 in the upper atmosphere from the combustion of fossil fuels, could enhance the greenhouse effect, leading to climate change. Arrhenius's findings were published when the environmental implications of the Industrial Revolution were beginning to be recognized, but it was only in the later decades of the last century that serious attention was given to the potential impact of increased CO_2 emissions on the world's climatic system. In the early 1970s, increased CO_2 production and rising atmospheric turbidity were identified as two important elements capable of causing climatic changes – rising CO_2 levels could cause warming and increased turbidity could cause cooling. (Calder, 1974; Ponte, 1976)

By the early 1980s, a growing number of investigations into global warming reversed the theory that the effects of rising CO_2 levels and increased turbidity could balance themselves out. (Manabe *et al.,* 1981; Schneider and Thompson, 1981; Pittock and Salinger, 1982; Mitchell, 1983; NRC, 1982 and 1983). This work revealed that scientists had underestimated the speed of the intensification of the greenhouse effect and the potential impacts of the resulting global warming on the eco-system.

Fact Sheet 8 (UNEP, 1993) from the Information Unit on Climate Change (IUCC) suggests that natural temperature fluctuations seem to be occurring on several timescales, some due to natural climate oscillations that therefore may be fairly predictable, but others may be completely random. Natural fluctuations may have conspired to make the late 1980s warmer than the underlying trend alone, but available statistics indicate that there is a genuine warming trend. Whether this trend is the effect of GHG emissions or a natural fluctuation due to some yet-to-be-discovered mechanism cannot be determined by analysing the global mean temperature alone. Such natural fluctuations appear to have occurred in the past, although not in the last 9000 years have the fluctuations been as great as the *projected* change over the present century. The conclusions of IUCC are that there is no climatic counterpart to the Antarctic ozone hole and that a single dramatic discovery to confirm global warming is not to be expected. However, if mankind waits for such a discovery, it may be well after it is too late to do much about it.

One of the most important and influential climate change studies was that of the Intergovernmental Panel on Climate Change (IPCC, 1995) when it predicted that over the next century, the earth's surface temperature might rise by a further 1.0 to 3.5°C, and that sea levels might rise by between 15 and 95 centimetres. It has conceded that some of this impact is probably unavoidable since it will result from current emissions. However, it would be unwise and potentially dangerous to ignore the mounting concern.

The IPCC simulated changes in the global mean average surface temperature for the period 1850-1990, and projected changes due to increases in greenhouse gases and CFCs relative to pre-industrialisation. From 1990:

- The high estimate referred to in IPCC 1995 as IS92e, is 2.5°C by 2100. This assumes the highest level of population and economic growth of all scenarios. The energy supply includes more conventional use of oil and a phase out of nuclear energy by 2075. Emission controls increase energy costs by 30% and CFC production phased out by 1997 by industrialized countries.
- The middle estimate (IS92a) is for a rise of 2.05°C in mean global average temperature by 2100. This uses the same population assumption as the high scenario, but lower economic growth. The energy mix uses less oil and includes more solar and bio-fuel energy. It also assumes controls on NO_x and VOC emissions and partial compliance with the Montreal Protocol.
- The low estimate (IS92c) of 1.3°C by 2100 uses the lowest population and economic growth scenarios, and less fossil fuel use. Other controls are the same as the middle scenario.

The IPCC concluded that:

- the balance of evidence suggests a discernible human influence on global climate;
- if CO_2 emissions were maintained at near current levels, they would lead to a nearly constant rate of increase of atmospheric concentrations for at least two centuries reaching almost twice the pre-industrial concentration level by 2100;
- for the mid-range IPCC scenarios of future emissions, and assuming the best estimate value of climate sensitivity, models project an increase in global mean temperature, relative to 1990, of about 2°C by the year 2100 – the uncertainty range being 1-3.5°C.

The UN Advisory Group on Greenhouse Gases (UNAGGG, 1999), estimates that doubling CO_2 concentration in the earth's upper atmosphere will result in an increase in the average global surface temperature of between 1.5 and 4.5°C, and that the greatest increase will be in winter at high latitudes. Temperature increases in winter at high latitudes would accelerate the hydrological cycle causing a 3-15% increase in global average precipitation and evaporation, and likely soil moisture reductions in mid-latitudes.

Claimed to be the most authoritative yet to support the global warming argument, the latest report of the IPCC (2001), is based on the panel's third comprehensive assessment, predicts that global temperatures could rise by up to 5.8°C over the twenty-first century. This would be a greater rate than it has been for the past 10,000 years. (Houghton, 2001).

Additional evidence purported to support the global warming argument is that of Buchdahl (1997:3) whose studies of records of several climate elements, reveal a global mean surface temperature change during the 20th century. Buchdahl claims that global mean temperature has already risen by between 0.3 and 0.6°C since about 1860.

Other change trends in precipitation, tropospheric temperatures and ice volume also have been observed. The North American Space Agency (NASA, 2000) has calculated that the Greenland ice sheet is thinning by half a metre per year as a result of global warming. It is believed that these climatic changes are the result of anthropogenic activities causing increased concentrations of greenhouse gases in the upper atmosphere.

More recent statistics from the UK Meteorological Office show that 1989 and 1990 were England's hottest years from records that date back to 1659. The Hadley Centre for Climate Prediction reported that 1997 was the warmest year for the planet's oceans and continents in 130 years of global temperature records. UK rainfall in 1997 was about 95%

of the average, which made it one of the driest 100 out of 250 years of rainfall records. February 13 1998 was the warmest February day in England on record, December 1998 was the warmest December on record and January 1999 was the warmest January of the twentieth century. All of which suggests that Britain's climate is changing – but these facts should not be taken as evidence of a long-term trend – nor are they proof of global warming.

A great deal of research has focused on global warming and its possible effects on climate, but the extent and timing of the phenomenon are not yet entirely understood. It is difficult therefore for climatologists to make accurate predictions without allowing for a wide band of scenarios. Human factors are particularly unpredictable. Technology, politics, socio-economic and demography determine the anthropogenic contribution to the level of CO_2 in the upper atmosphere, but the effect and magnitude of the variations in these elements are impossible to predict with any degree of accuracy.

Since there are many variables in the predictions, Kemp (1994) concludes that the reality of the situation may only become apparent when the changes have occurred. But the uncertainty means that those who are unconvinced or have vested interests in retaining the *status quo,* can argue that there should be no action until there is absolute evidence of global warming. Even if the weight of evidence for action is undisputed, then the options must be studied and strategies implemented to stabilize the global climate.

Estimates of the causes of climate change predict a wide range of effects. More intensive research is needed to reduce the discrepancies between the general circulation models on variables such as cloud feed-back which is probably the main factor for divergence resulting in the IPCC's wide range of mean global temperature rise.

1.2.4 Arguments against warming theory

Substantial natural climate variability occurs due to interactions between the various components that influence the earth's climate system (the atmosphere, the oceans, the land, the ice and the biosphere), (Houghton, 2000). Superimposed on these variations, are climate changes due to other variable factors that affect the climate – some of which are biogenic, others are anthropogenic. Houghton's conclusion, based on IPCC assessments, is that the influence of anthropogenic factors, especially emissions of CO_2, are likely to be dominant during this century.

However, many scientists argue against the case that global warming will result from increased levels of greenhouse gases from anthropogenic sources. For example, Weirauch (1999) cites Professor Patrick J Michaels of the University of Virginia. Michaels claims that the record temperatures of the summer of 1998 were the result of a strong El Niño in a period during which temperatures continue to reflect a warming that mainly took place in the first half of the century. Michaels claims that observed global warming is below that predicted by computer models that served as the basis for the United Nations Framework Convention on Climate Change (UNFCCC).

Reed (1995) dismisses global warming theories, basing his argument on the following grounds:

- the consequences of the physics of the greenhouse effect are not well understood, and most of what is known is based upon hypotheses and is supported only by models;
- scientific models disagree as to whether a significant temperature rise should be detectable by now;

- global temperature data is only available for the past century or so; this period may be too short to make a reliable prediction about global warming;
- temperature data is lacking for certain regions of the Earth, especially before 1900;
- some of the variations in temperature data may have been caused by changes in data collection techniques over the years;
- changes in local environments may have caused changes in local temperature measurements, therefore it is difficult to distinguish a local feature from a local trend in the data;
- global mean temperature is hard to define and measure;
- there are many factors, besides greenhouse gases, that affect global climate;
- natural climate changes make it difficult to detect long-term trends.

There are claims that the earth is *cooling*. According to Eggenstein (1985), scientists were unanimously agreed that the heat energy in the northern oceanic regions had decreased by 5% over the 20 years preceding 1975, and that the rate of heat loss had risen. Eggenstein quotes the finding of the Geological Observatory of Columbia University in New York, that the permafrost had extended by 12% between 1967 and 1984, the ice masses of Antarctica increased by 10% in 1966 and 1967, and that over the 30 years (1950-1980) the mean temperature in the Northern Hemisphere had *dropped* by 0.5°C. Although carbon dioxide emissions had increased many times the level in 1940 level, some scientists allege that the climate is getting colder.

Eggenstein refers to Bryson's work for the US Central Intelligence Agency (CIA). Bryson claims that the potential for increase in global temperature due to GHG is counteracted by the negative effect of increasing dust masses in the atmosphere, and that the Earth would have been even colder had it not been for the measurable and still increasing volume of carbon dioxide. There is no scientific evidence that shows this to be so.

There have been 'natural excursions' in the Earth's climate that were unconnected with recent increases in greenhouse gases from anthropogenic sources. There are some compelling arguments that the sun's activity levels have the most significant effect climate.

Solar influence

NASA climatologist Robert Wilson proposes that there is a link between observed global temperature fluctuations and solar activity in the form of sunspots, and that variations in the energy output of the sun have significantly affected the Earth's climate for centuries. (NASA, 1998) Other studies have reinforced this theory. (Zimmerman, 1994; Hecht, 1998) who traced it back at least as far as the Little Ice Age 1645-1715 which coincided with a period of exceptionally low sunspot activity.

NASA studies indicate that sunspot activity is currently at its highest level for 300 years, and predicted activity would peak in 2000. It is implied that there are strong statistical associations linking current trends in the Earth's surface temperatures to trends in solar activity.

Although the mechanism linking the sunspot cycle to the Earth's temperatures is unclear, the work of Butler *et al.*, at Armagh Observatory has produced evidence that solar activity affects the Earth's climate. (Cowen, 1994:271). Analysis of data gathered at the observatory since 1795 suggests that average surface temperatures vary with the length of sunspot cycles.

Solar winds are linked to sunspot activity and may explain why the Earth gets warmer during peak sunspot activity. According to Hecht (1998:20), the flux of charged particles in the solar wind results in a cascade of lower-energy ions escaping into the Earth's atmosphere. The latent heat released affects cloud cover and reduces the level of solar radiation reflected back into space.

Satellite measurements show that the sun dims and brightens over the 11 years sunspot cycle. Research at Columbia University's Center for Climate Research at Altadena, California revealed that the sun is emitting more heat now (2000) than it did ten years ago. Even small changes in the activity of solar radiation during a sunspot cycle, might be responsible for the observed changes in the Earth's climate. Baliunas and Soon (1995) predict that solar brightness and the Earth's atmosphere temperatures will decline in the next 50 years due to a predicted longer sunspot cycle. If this prediction is fulfilled, it could balance the effect of an enhanced greenhouse effect.

Lawrence (1996) claims that the 11-year solar cycle is a guide to long range weather forecasting. Lawrence predicted correctly that Britain's rainfall would tend to peak from 1998 to 2000 on the approach to the 2000 sunspot maximum.

Kerr (1995) claims that there is evidence that the world's oceans have been warming and cooling in time with the sunspot cycle. It is implied that the sun could have been responsible for as much as half of the global warming observed in the last century. If this is correct, the build-up of greenhouse gases will be less significant in estimates of future climate change.

Adaptive infra-red iris

Another credible argument is proposed by Lindzen, *et al.,* (2001) who observed that the tropical Pacific Ocean is part of a negative feedback loop. At higher ocean temperatures, there is less high altitude cirrus cloud cover than when the ocean is cooler. Cloud (water vapour) is a greenhouse gas reducing re-radiation of heat from the earth's surface into space. When the ocean warms, fewer cirrus clouds form, more heat is lost to space, and the ocean cools. The phenomenon has been called the "adaptive infrared iris" – opening and closing in order to maintain a more constant level of heat.

According to Lindzen, the relationship between high altitude cloud cover and sea-surface temperatures is not accommodated in climate change models. The implication of the 'adaptive infrared iris' is that climate sensitivity to changes in greenhouse gas levels is much lower than the IPCC assumes. Lindzen finds that if the same negative feedback observed in the tropical Pacific is common to all tropical oceans, then the IPCC estimates of warming should be reduced by about 60%. This adjustment to the IPCC estimates would revise the range of potential warming to between 0.6°C and 2.3°C.

Natural excursions

The temperature of the Earth varies naturally over a relatively wide range. For example, surface temperatures of the Sargasso Sea have varied over a range of approximately 3.6°C during the past 3000 years, (Robinson *et al.,* 1998). After a warm period known as the 'Medieval Climate Optimum' about 1000 years ago, the Earth experienced the 'Little Ice Age' since when, global temperatures have been gradually recovering. According to Robinson, temperatures are still below the average for the past 300 years. Although global temperatures have been much higher than now during much of the last 3000 years, there is no recorded evidence of catastrophic consequences.

Summary of argument

All of the arguments have some degree of scientific merit. None of the arguments is totally indisputable. The physics of the greenhouse effect are not fully understood and much of the theory is based upon hypotheses and supported only by using global temperature data for the past century or so. This may be too short a time to make a reliable prediction about global warming. Some of the observed variations in temperature data may have been caused by changes in data collection techniques over the years.

There are many factors, besides greenhouse gases, that affect global climate. It is difficult to detect long-term trends. Scientific models disagree as to whether we should yet be able to detect a significant temperature rise.

Discrepancies in data

Recently, there have been other conflicting arguments over global warming following claims by some American scientists that data from satellites suggest that the Earth's atmosphere is cooling, rather than warming. There are counter-claims that this is the result of an error. The argument centres on weather satellites' instrumentation from which the data is taken.

Altitudes of satellites decay due to atmospheric drag. As satellites fall, the angle of the 'view' changes relative to the Earth. (Hansen *et al.,* 1998) This is blamed for inconsistencies in data. Altitude change is not significant for temperature measurements of the stratosphere and middle troposphere. However, it may be significant for measurements taken of the lower troposphere, particularly since altitude decay is most rapid near the peak times of solar activity that occurred around 1980 and 1990. Hansen refers to Wentz and Schabel's calculation that the mean correction for 1979 to 1995 was +0.12°C per decade. According to Hawkes (*The Times, Aug 13, 1998, p. 11*), this concurs with independent observations by Prabanka *et al.*, which show warming at 0.11°C per decade.

Climatologists rely on systems that were not designed for climate monitoring. On this point, Gaffen (1998) stresses that more advanced methods are needed for monitoring temperatures of the Earth's atmosphere. Gaffen shows that after correction for orbital decay of observation satellites, the lower troposphere, (the lowest 10 -15 km of the atmosphere) shows warming of 0.07°C per decade. Although the trend is small, it is similar to longer-term estimates from surface data published in the IPCC Second Assessment in 1996.

Hansen suggests that the global warming issue has been confounded for several years by satellite observations of a cooling trend in the troposphere. These observations conflict with the measurements at meteorological stations that show surface warming, and with climate models that predict warming both at the Earth's surface and in the troposphere. However, the discovery of an oversight in the satellite data analysis removes the inconsistency between surface and satellite observations. Furthermore, the modified temperature profile is similar to published climate model simulations. Hansen is convinced that warming trends of both surface and troposphere are sufficiently clear that the question should no longer be, 'is global warming is occurring?' but 'what is the rate of warming?'

Hansen's observes that independent measurements of tropospheric temperature trends are received from radiosondes (weather balloons) covering the Northern Hemisphere show the tropospheric temperature trend as almost zero to +0.10°C. This supports the argument *for* global warming, although the anti-warming lobby has used the satellite data to show cooling of the lower troposphere.

There is also a contradiction between ground-based and satellite-based temperature readings. It is claimed that balloon-based measurements of the atmosphere temperatures during the period 1979-1995, agree with the satellite data indicating a small cooling but over a longer period from the 1950s, the balloon data shows an increase. Hawkes quotes the work of Brown at the Hadley Centre for Climate Prediction and Research at the UK Meteorological Office that suggests that over the relatively short period covered by the satellite data, natural temperature fluctuations in the atmosphere could have caused the anomaly.

Conspiring factors

Apart from greenhouse gas levels there are other variable factors, some of which conspire to confuse the global warming issue. Like the conflicting satellite and balloon data, the global warming theory is confused by the opposing influences of water vapour on the Earth's climate. Global climate change models show that increased warming will lead to greater evaporation from the oceans. Water vapour contributes to the greenhouse effect. Therefore if carbon dioxide emissions double and there is more water vapour, the warming could be substantially more than that predicted as a result of increased concentrations of greenhouse gases alone. Although in some climate change models, more cloud may amplify warming, more cloud resulting from increased evaporation may reduce the degree of surface heating and thus mitigate the greenhouse effect of increased water vapour in the atmosphere.

If there were greater high latitude precipitation *and* glacier melting, the salinity of the seas near Greenland would fall and lower the density. This factor, in addition to warming (which may be much greater at this latitude than the global mean), would reduce the gradient of the Atlantic Ocean thermocline. Together, the changes could mean that the cold surface waters might no longer sink into the deep ocean as they do now. The Gulf Stream would cease. This would reduce the capacity of the ocean to absorb CO_2. There is a possibility that the reduced warming effect on northern Europe could be offset by global warming. But there is no guarantee that the two influences will balance.

The mild winters experienced recently in the British Isles may be a precursor to extremely cold winters as a result of changes in the Atlantic currents and their direction. If the stream moves northward, it will reduce the warming effect on the British Isles, and reduce the snow and ice cover over Scandinavia and Northern Europe. In addition to lowering the density of the North Atlantic, reduced snow and ice cover will reduce the re-radiation of solar heat. Surface temperatures will rise. The combined effects of these changes could create a totally new weather regime in the region.

Two scientific facts are undisputed despite considerable argument. The first is that additional carbon dioxide has been accumulating in the earth's atmosphere over the past 100 years. The second is that the gas traps heat from the sun's energy when it is absorbed by the earth and then re-radiated. There is uncertainty regarding the amount by which the earth's climate would heat up in response to further accumulation of carbon dioxide in the Earth's atmosphere.

But if there is no immediate action, and there *is* a link between manmade greenhouse gas emissions and climate change, by the time we have indisputable evidence it might be too late to save the planet's populations from the disastrous consequences. If global warming is not due to rising levels of GHGs – there are other valid ecological reasons for reducing CO_2 emissions.

The debate is not closed. If there is discernible global warming, it may be as a result of increasing levels of greenhouse gases from anthropogenic activities. Solar activity could explain recent 'abnormal' weather events. Observed temperature trends may be 'natural excursions'. Although without proof, each proposition has some degree of validity. The coincidental occurrence of more than one cause of warming could be catastrophic.

Although the arguments have not abated, with the exception of the USA, governments have been persuaded to act.

1.2.5 The possible consequences of global warming

Social

All should be concerned about the possible social and economic consequences of climate change – the possible effects of which include serious flooding, severe storms, heat waves and economic damage. Masood and Garwin (1998) claim that the Kyoto protocol on climate change setting the targets for industrialized countries to reduce greenhouse gases by 5% from 1990 levels by 2012, will reduce the projected 1.4°C temperature rise by only 0.05°C. It is estimated that such a temperature rise would put one billion people at risk from water shortages, 23 million at risk from coastal flooding, and 22 million from hunger. The Kyoto targets are modest and may not reduce these risks.

Houghton (1998) claims that unless the potential for climate change is reduced, there are serious risks of heat extremes, droughts, floods and rising sea levels. Some islands in the Pacific and Indian Oceans will disappear, as will large areas of Bangladesh and southern China. Even if the world does have enough food, energy and other raw materials to meet the requirements of present and future generations, the challenge will be to limit the impacts of their production, transformation, and consumption.

The IPCC (2001) report issued at its Shanghai meeting, warned that the possibility of an increase of 5.8°C in global mean temperatures, could cause sea levels to rise up to three metres as a result of melting Antarctic ice and expansion of sea water. But forecasts by the Natural Environment Research Council (NERC, 1998) indicated that if every country met its Kyoto commitment there would be a reduction of about 6% in the predicted global mean warming by 2100, from 2.4°C under the "business as usual" scenario, to just over 2.2°C. And because of the long lag times, the effect on sea level rise will be just over 1%. However, NERC warns that to prevent CO_2 concentrations from rising further, it would be necessary to reduce current emissions by 60%.

Political instability in the developing world leads to risk of conflict with a potential for escalation. The problems resulting from 'natural' disasters may be compounded by disasters attributable to climate change. Lack of food and the basic needs of affected peoples could give rise to further political effects – effects such as regional disturbances over agricultural land and other essential resources. The UK government recognizes that the risks of wars must be taken seriously. The problems faced now are more complex than during the 'cold war' era. During that period there were only two political philosophies and therefore two potential enemy groupings. Today there is cause for growing concern created by the multiplicity of regions where there is potential for conflicts both national and cross-border.

The burning of fossil fuels is thought to be the most important source of the problem of global warming. The burden of reducing global warming and the possibility of climate change is on the developed world. Humans are the custodians of the earth and should act accordingly to the implicit responsibility for the future of humanity and the Earth's eco-systems. Not all are in a privileged position to make major contributions; but it is essential that those who can – do, if not voluntarily then by persuasion. The developed countries have an obligation to solve the issues not only to avert the indirect impacts on their own economic and political systems, but also to fulfil their moral responsibilities.

Economic

Humankind depends on fossil fuels for the increasing amount of energy needed to meet the demands imposed by worldwide economic growth. Fossil fuels are available and affordable, and will be the principal source of energy for economic development. If the use of fossil fuels is restricted for environmental reasons, it could have negative effects on economic development.

Population growth and the associated economic activities cause environmental damage, but global warming is different from other environmental concerns since economic development is *directly* linked to the use of fossil fuels and the associated emissions of CO_2. However, economic growth not only increases the environmental burden, it also provides the conditions necessary to protect the environment. (Kaya *et al.*, 1997)

In 2000, the world consumption of primary energy was almost 10,000 million tonnes of oil equivalent (Mtoe), of which 80% was from the combustion of fossil fuels. (Institute of Prospective Technological Studies, undated). Primary energy consumption is predicted to rise by 50% by 2020 with at least 80% being fossil fuels.

It is possible that abatement measures in developed nations could create 'leakage', whereby CO_2 reductions in a developed country result in CO_2 increases in other regions. Therefore, it is important that any economic measures to encourage energy efficiency, such as carbon taxes, do not adversely affect the international competitiveness of developed countries committed to emissions reduction.

However, if leakage does occur, it should be offset in the longer term. Increased economic activity in the developing countries would accelerate the rate of technological development and reduce the time by when they will be able to commit to emissions reductions themselves.

The build up of greenhouse gases in the atmosphere resulting from the imbalance created by industrial activities may mean that some climate change is inevitable. If this is so, resources committed to combat climate change could be diverted to finding ways to adapt to the changes instead of reducing emissions of greenhouse gases. This approach assumes that climate change is inevitable and if it is, then international efforts should concentrate on ways to adapt to it.

If global warming does occur, then climate changes that result could lead to more floods *and* droughts. But scientists believe that many of the 640 million people currently at risk from hunger could be helped by 'drought proofing', which could take the form of better irrigation, breeding more drought resistant crops, and developing buffer stocks of food.

At the national level, referring to a report to government ministers prepared by Environmental Resources Management (ERM), the then Environment Minister, Michael Meacher, conceded that the UK could not escape from all of the effects of climate change and that at least £1.2bn will be needed during the next 50 years to improve sea and river defences in England and Wales. *(The Times, May 16, 2000, p. 12)* Some coastal areas, especially in Eastern England may be abandoned to the sea because it could be uneconomic to defend them. The cost for sea defences could be as high as £500m a year by the middle of the century.

The ERM study identified priority areas for early action and estimated likely costs. For example, by 2050 it could cost more than £15 billion to make houses cooler in summer, and able to withstand storms, subsidence and heavy rain. Damper winters will increase levels of condensation and mould, and monsoon-like rain predicted under climate change forecasts could cause other damage to the fabric of buildings. Converting offices and factories also could cost up to £15 billion.

ERM predicts acute water shortages; the South East of England being particularly vulnerable could have at least 20 per cent less water available than now. To meet the predicted shortfall, new reservoirs and schemes to collect winter rain could cost as much as £44.5 billion. These are some of the economic impacts that could arise for the UK.

Many scientists believe that the current emissions reduction targets will not avoid dangerous levels of climate change and should not be mistaken for effective climate management. Science, engineering and technology can provide some solutions to help to deal with the consequences, but sociologists, economists and political scientists also have an important part to play.

1.3 The development of global warming as an international issue

Thirty years have elapsed since there was real awakening to the potential seriousness of the issues surrounding the effects of increasing economic and population growth and its influence on energy demand. The associated risk of climate change and the need for sustainable development led to international action.

1.3.1 Awakening

The Club of Rome: 1968

The Club of Rome is an informal international association of people with diverse backgrounds but with the common interest of fostering understanding of the varied but interdependent components of the global system. A series of meetings have taken place, the first of which was held in Rome in 1968. The early meetings culminated in the decision to initiate a project on the Predicament of Mankind.

The account of the findings of the project research was published for general readership in 1972. Entitled 'The Limits to Growth', (Meadows *et al.,* 1972) the report was widely publicized and generated considerable international debate on the possible consequences of world population growth, and the Earth's limited resources to satisfy demand and capability to tolerate the pollution of the environment resulting from resource use and its waste. Despite the great interest in the report, it was to be 20 years before it had much effect on industrial activity, business in general, or on government policies.

UN International Conference on the Environment – Stockholm: 1972

The United Nations (UN) International Conference on the Environment, convened in Stockholm in 1972, could be regarded as the beginning of political concern for environmental issues at formal international level. The United Nations Environment Programme (UNEP) was establishment to create a basis for the consideration and co-ordinated action of the UN on the problems of the human environment. UNEP was initiated to provide an integrated and interactive mechanism through which a large number of separate efforts by intergovernmental, non-governmental, national and regional bodies in the service of the environment are reinforced and interrelated. UNEP advocated a concept of environmentally sound development, which later led to the adoption of the 'Sustainable Development' concept in the Brundtland Commission Report (1997). The concept of sustainable development evolved into the action programme called Agenda 21, and was later adopted at the 1992 United Nations Conference on Environment and Development (UNCED).

1.3.2 The definition of the problem

The early studies of the Club of Rome suggested that the current way of life, particularly in the developed countries, cannot be sustainable indefinitely, and possibly not for more than a few generations longer. Inequality in living standards, consumption of natural resources, and the impacts of humankind's activities on the earth's eco-system raised serious concern for sustainable development. But a sustainable global society cannot be achieved without international government intervention to co-ordinate policies and actions. This presented some complex issues that lead to a hiatus lasting 15 years when very little happened. Interest in the issues were re-awakened in 1987 by the publication of the Bruntland Commission Report, (1987) the Montréal Protocol and the establishment of the Intergovernmental Panel on Climate Change (IPCC).

Bruntland Report: 1987

The World Commission on Environment and Development published its report *'Our Common Future'* – known also as the 'Bruntland Report' after Norway's prime minister at that time, Gro Harlem Bruntland who chaired the Commission. The report gave its concise definition of sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. Since the environment affects everyone, all people have a vested interest in creating a more sustainable world. But two of the principal aims of sustainability are to meet the needs of all, but particularly the *essential* needs of the poor, and to accept the limitations imposed by the state of technology and future needs.

The Montréal Protocol: 1987

The irrefutable scientific evidence that there was a loss of stratospheric ozone over Antarctica led to the international agreement that set a target to reduce emissions of chlorofluorocarbon (CFC) gases by 50% by 1999 to avert further damage to the ozone layer. Known as the Montréal Protocol, it was signed in September 1987. The international response to this was seen as encouraging for future actions to curb greenhouse gas emissions.

Intergovernmental Panel on Climate Change: 1988

Growing concern over the potential for climate change, led to the establishment in 1988 of the Intergovernmental Panel on Climate Change (IPCC) with the task of carrying out an assessment of the issues. The panel is a committee of scientists in various disciplines – under the auspices of the UN and the World Meteorological Organisation (WMO).
By reviewing and reporting on the scientific evidence on climate change, the work of the IPCC underpinned the international community's decision to develop the United Nations Framework Convention on Climate Change (UNFCCC).

The Panel's 1995 report declared that the balance of evidence suggests that there is a discernible human impact on global climate. The panel confirmed that emissions resulting from human activities are increasing substantially the atmospheric concentrations of greenhouse gases (CO_2, CH_4, CFCs and N_2O). These increases could enhance the greenhouse effect, resulting in an increase in global mean temperature. IPCC's assessments confirmed that concerns about global warming from greenhouse gases were justified. This led to calls for more positive action by developed countries whose industrialisation is believed to be the primary cause of the higher levels of greenhouse gas concentrations in the upper atmosphere.

Assessments identified also the effects of sulphate emissions and ozone depletion on global warming. Since the rate of ozone depletion is believed to increase at lower temperatures, an increase in the earth's average surface temperature will result in a temperature reduction of the upper atmosphere that may lead to increased ozone loss. Such an effect could negate the benefits achieved as a result of banning the use of CFCs.

The IPCC assessments provided essential information for the generation of subsequent reports that eventually led to the Earth Summit in 1992 and the Kyoto Protocol of 1997.

The Earth Summit: 1992

At Rio de Janeiro in June 1992, the IPCC presented its second assessment of the science of climate change to the United Nations Conference on the Environment and Development (UNCED). The meeting became known as the Earth Summit when the UNFCCC Protocol was formulated and signed by delegates representing more than 150 countries.

Developed countries pledged to reduce greenhouse gas emissions to 1990 levels by the year 2000, and thereafter to reduce emissions in stages by 2005, 2010 and 2020. The aim was for an agreement on a 7.5% reduction by 2005, and 15% reduction in emissions of

CO_2, methane and nitrous oxides by 2010. Based on a business-as-usual scenario, the commitment to reduce to 1990 levels by 2000 is equivalent to a CO_2 emissions reduction of 10–15%. (Cline, 1997)

1.3.3 Action

Under the auspices of the UNFCCC, a series of Conferences of the Parties (COP) took place – beginning in 1995. The objective was to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. (Houghton, 2000a)

Conferences of Parties: 1995

The first Conference of Parties (COP–1) was held in Berlin in 1995, to establish the organisational structure of the body, its terms of reference, and set out a programme of activities. The second meeting (COP–2) was convened in Geneva in 1996 to evaluate the implementation of the UNFCCC and the progress made in the negotiation process initiated at the first session. It was at this session that the protocol was negotiated to strengthen the commitments of the Parties and for adoption at the third session of the Conference of the Parties.

The Kyoto Protocol: 1997

In December 1997, at the third Conference of the Parties (COP–3) in Kyoto, Japan, thirty-eight industrialized countries adopted an agreement to become known as the Kyoto Protocol. The agreement committed developed countries and countries making the transition to a market economy to achieve targets for decreasing their emissions of greenhouse gases. These countries, known under the UNFCCC as Annex I Parties, committed to reducing their overall emissions of the basket of six greenhouse gases by 5.2% below 1990 levels over the period between 2008 and 2012. Specific targets were set for each country.

The Kyoto Protocol established ways to promote the most cost effective global reductions of GHG emissions. It included the basis for three mechanisms to assist Annex I Parties to meet their national targets cost-effectively. These were – an emissions trading system, joint implementation of emissions reduction projects between Annex I Parties, and a clean development mechanism to encourage joint projects between Annex I Parties and developing countries.

GHG emissions of developed countries are linked principally to economic activity, and 88% of all GHGs are energy related. The international commitment affects some countries more than others. Under the Protocol, large polluters such as the EU will have to reduce emissions by 8%, the US by 7% and others including Japan and Canada by 6%. A group, which includes Russia and New Zealand, must stabilize emissions, and another group including Norway (1%) and Australia (8%) is permitted to increase emissions.

The cuts agreed for greenhouse gas emissions were modest compared to the EU's original proposal of 15%, but were seen as an important first step. Before the Kyoto meeting, the

UK had committed unilaterally to a cut of 20% in CO_2 emissions by 2010 compared to 1990 levels. The EU appeared to be the only party to the Earth Summit to have taken seriously the pledge to reduce greenhouse gas emissions.

The Kyoto protocol was opened for signature in March (1998) and had to be ratified within a year by at least six countries representing 55% of total 1990 emissions – before it came into effect. The reductions proposed on emissions of greenhouse gases have no legal force until the accord is ratified by signatories. The EU's environment minister Ritt Bjerregaard and the British politician John Prescott, as president of the EU council of ministers at the time, signed up to the Kyoto protocol in April 1998 at the United Nations in New York, as did Japan. The EU, including the UK, aims to ratify its commitment so that the Protocol comes into force in 2002. Ratification by some countries is not expected until 2003. Although the US signed up to the Kyoto protocol with 59 other countries, the Bush administration does not intend to proceed with ratification.

Although the agreement is legally binding there are no provisions for sanctions against countries that fail to meet their targets. According to the United Nations, 'political and moral pressure with an emphasis on co-operation and mutual support' will be the method used to keep the process on track. (Industrial Relations Services, 1998)

If IPCC predictions are correct, the Kyoto targets can be seen only as a 'first step' for the international community, and represent only the targets that are politically achievable at present rather than which are actually required to stabilize atmospheric concentrations of greenhouse gases. In the longer term, the real value of Kyoto may not be its direct impact on limiting greenhouse gas levels, but as a precedent for co-ordinated international action to combat climate change.

Second Earth Summit: 1998

The fourth Conference of the Parties (COP-4), under the UNFCCC, was held in Buenos Aries, in November 1998. This became known as the Second Earth Summit when the latest findings of the Hadley Centre were presented to more than 5000 scientists and politicians, representing 170 national governments. It was predicted that unless there was a reduction of GHG emissions, by 2050 vegetation would lose its ability to absorb more carbon dioxide thereby accelerating the accretion of CO_2 in the atmosphere.

The findings of the Hadley Centre indicated also that:

- the average global temperature in 1998 would exceed 1997 – the hottest on record;
- the 1997/9 El Niño was the most extreme on record;
- man-made GHG emissions have made a substantial contribution to increase global temperatures in the last 50 years;
- a further $3^{o}C$ warming in the next 100 years – the land warming faster than the sea; and
- a slowing down of the North Atlantic thermocline of about 20% by 2050 – although Europe still warms.

The result could be that by the 2050s:

- tropical forests die in parts of northern Brazil;
- tropical grasslands transformed to desert or temperate grassland;
- 20% more people at risk of hunger in Africa;
- 170 million extra people living in countries with water stress; and
- increased exposure to malaria.

The summit meeting closed with an agreement to set a deadline of the end of 2000 to finalize the design of methods to deliver CO_2 reductions internationally by joint implementation, emissions trading and the clean development mechanism, all of which were agreed in principle at Kyoto. The methods were designed to allow developed countries to target action in other countries to meet some of their Kyoto obligations, and to involve the developing nations in the process.

1.3.4 Hiatus

Fifth Conference of Parties: 2000

At the fifth Conference of the Parties (COP–5) to the Climate Change Convention in Bonn in November 1999, there was not much progress towards establishing ground rules that would be needed to implement the Kyoto Protocol on global warming. Delegates failed to reach agreement on substantive issues including international emissions trading, ways to make it simpler to export technologies to developing countries and Protocol enforcement rules.

The UK delegates proposed that the EU should set an example to other developed countries by making a commitment at the next Conference of the Parties – subject to outstanding issues being satisfactorily resolved – to ratify Kyoto as soon as possible to encourage enough other countries to ratify, to enable the Protocol to be enforced by 2002.

Sixth Conference of Parties: 2000

The sixth Conference of Parties (COP–6) held at The Hague in November 2000 failed to finalize the guidelines for reducing greenhouse gas emissions agreed at Kyoto. EU delegates rejected a US proposal to create and use carbon 'sinks' to limit its need to cut greenhouse gas emissions. European delegates and environmentalists insisted that cutting emissions, particularly of carbon dioxide, must be the primary mechanism to reduce the effects of climate change.

Some industrialized countries, including the USA, want to meet their commitments under the joint implementation mechanism by funding reductions in non-Annex I countries rather at home. Other countries want to trade emissions but will not accept a limit of 50% of their total agreed reduction.

The Hague meeting was suspended when major issues could not be resolved. Talks were resumed in Bonn in May 2001, when the Parties reached broad agreement on the outstanding issues of rules for emissions trading and other market-based mechanisms, methods for crediting sequestration by carbon sinks, funding for developing countries to combat and cope with climate change, and mechanisms to encourage and enforce compliance with the Kyoto targets. It was hoped that the settlement made could be ratified at the next full meeting of the Parties.

Seventh Conference of the Parties: 2001

Marakesh, Morocco was the venue for the most recent Conference of the Parties (COP–7) in October and November 2001. There were over 4000 participants from 172 national governments, 234 intergovernmental and non-governmental organisations, and the world press media.

The main objectives for COP–7 were achieved. The Bonn agreements were translated into legal documents defining the operating rules for the instruments and institutions created under Kyoto. The next step will be the ratification of these by industrialized countries to bring the Protocol into force before the World Summit on Sustainable Development planned for September 2002 in Johannesburg, South Africa.

1.3.5 International measures to reduce the risk of climate change

It is unlikely that global warming will be averted by the emissions reductions agreed at Kyoto. Indeed it seems unlikely that the protocol will be ratified by all of the signatories – the most significant defaulter being the USA. In March 2001, the US Senate voted 95-0 not to ratify the Kyoto accord. The EU contribution to the agreed reduction will be worthwhile but without reductions from other industrialized countries, it will not make much difference to the rate of increase of GHG concentrations in the upper atmosphere. It was widely accepted that the Kyoto agreement in 1997 was only a beginning but the next phase in the process should also be debated as soon as possible in view of the time lags between agreement, target dates and effect on concentrations.

The global economy can be viewed as a complex matrix of direct and indirect links. Each nation has its unique political system. Each has economic policies and strategies by which to achieve them. The wealth and economic strength of nations depend upon many factors such as industrial maturity, indigenous resources, geographical location, infrastructure, population size and distribution, and standards of education, (Landes, 1998). However, all nations are interdependent today since there are few major barriers to international trade in goods and services. Furthermore, the globalisation of business through multinational companies and intergovernmental and institutional co-operation has a profound influence on international politics and economies. National environmental policies, strategies and performances are to some degree also dependent upon these diverse influences.

The Kyoto agreement in the first phase concentrates on abatement of greenhouse gases in the developed countries, but includes measures that these countries might undertake with developing countries. In the longer term however, emissions limits in developing countries will be necessary also if the problem of global warming is to be addressed.

1.4 Outline of problem

The global warming theory has been discussed in the wider context of the potential impacts on the Earth's climate. To address this, international action has been taken to reduce greenhouse gas emissions by developed countries. To meet the commitments made by the international community, all sectors of the UK economy must reduce energy wastage. This is seen as a problem by industries that use large amounts of energy for processing. For example, it presents a particular problem for foundries where metal melting uses the major proportion of the energy needed to produce castings.

To encourage lower energy use by business, the government has introduced the climate change levy (CCL). However, in its present form the scheme could adversely affect the competitiveness of the UK's energy intensive industries and lead to their closure. Apart from the impact on the UK economy, there is an attendant risk that the products of such industries could be made in countries where there are no restrictions or economic penalties for inefficient energy use.

The use of economic instruments to encourage reduced industrial energy use is important therefore on two counts – it must not reduce competitiveness in order that the manufacturing capability of the UK is retained (including energy intensive industries), and it must not lead to CO_2 emissions being exported to unregulated countries as a result of closure of UK facilities. The latter consequence has become known as 'leakage'.

There are many objections to the CCL, mainly based on the claim that it would reduce international competitiveness. If the UK is to have a thriving industrial sector in its economy *and* meet carbon-related emissions targets – the current arrangement of a levy on energy used by business may fail. The system will probably create employment in the service sector by lowering the cost of labour. However, any gain in employment could be at the expense of more energy intensive businesses.

The levy scheme was adapted to satisfy some of the criticisms. As amended, the CCL provides discounts for industrial sectors that sign legally binding agreements to reduce their specific energy consumption over the period to 2010. But in its present form the CCL is a complicated tool. The scheme is cumbersome, will be expensive to administer by both business and government departments, and is not guaranteed to deliver the reductions in energy use to meet the government's targets.

A simpler alternative to the existing climate change levy scheme is needed to meet the government's energy saving targets for business in a more equitable way, without impairing the competitiveness of energy intensive sectors of manufacturing. A hypothetical alternative based on practical research of energy use and sources of energy waste in the aluminium casting industry is investigated.

1.5 Glossary of Terms & Definitions

Average mould yield – average mould yield for either a process or site, is a percentage calculated by dividing the weight of useful product by the weight of metal cast.

Bale-out – a melting or holding furnace from which molten metal is removed by baling with a ladle – either manually or automatically.

CH_4 greenhouse effect factor – greenhouse warming potential of methane calculated as a CO_2 equivalent.

Climate change levy – a levy charged on energy used by businesses in the UK.

Corrected gas consumption – quantity of gas used in m^3 after applying a correction factor to meter readings to compensate for supply pressure.

Dross – an accumulation of metallic oxides and other residual impurities on the surface of molten metals.

Economic instrument – policy instrument that works by affecting prices, such as tradable permits, taxes, levies or duties.

Efficiency – ratio of useful work done to total energy expended in a process.

Electricity supply industry (ESI) emissions factor – the primary energy equivalent of delivered electricity. (see also Primary energy equivalent conversion factor).

Energy – the ability to do work.

Energy intensity – energy consumption per unit of GNP.

Energy use – the conventions used in this work are those commonly used in industry. Energy measured at the point of use (delivered energy), is metered in m^3 for gas and kWh for electricity. For purposes of greenhouse gas emissions evaluations, energy is measured as 'primary' in kWh_p. For electricity see ***Primary energy equivalent conversion factor.***

Fiscally neutral – having no net effect on the national exchequer's annual revenue.

Foundry types – are defined in this work by the casting processes employed. (eg. sand, die, investment).

Furnace efficiency – ratio of energy transferred to the charge material to the total energy input to a furnace.

Gas consumption – measured by 'turbine' meters in m^3, corrected for supply pressure and converted to kWh_p.

Good quality CHP – is defined by the DTI as energy conversion efficiency in excess of 70% under normal operating conditions of combined heat and power equipment.

Gross efficiency = Furnace efficiency

Investment casting – a casting process whereby wax patterns are progressively coated with ceramic slurry to form a ceramic shell. The wax is melted out to leave a ceramic mould into which liquid metal is poured.

IPPC – Integrated Pollution Prevention & Control Directive. The European Council adopted the Integrated Pollution Prevention and Control (IPPC) directive in September 1996 and national legislation was implemented by EU member states in 1999. IPPC, regulated by the Environment Agency (EA), aims to reduce pollution to the environment as a whole, by means of permits based on the application of Best Available Technology (BAT), as regards cost, benefits and economic feasibility. It is a holistic approach to pollution that takes into account a wide range of environmental impacts including process energy efficiency and consumption of raw materials. In the UK, installations covered by Annex 1 of the directive are required to obtain authorisation to operate.
The IPPC Directive is designed to prevent or reduce emissions to air, land and water from a number of activities including part of manufacturing industry. Over 60% of industrial energy consumption is covered by IPPC. The Directive includes a requirement to use energy efficiently. Sectors covered by IPPC are eligible for a discount of the climate change levy if agreements are entered into. The government proposed that participation in a negotiated agreement should be taken into account when determining the action required on individual sites in order to meet the energy efficiency requirement of IPPC.

Kyoto Protocol – an agreement reached at the Third Conference of Parties to the United Nations Framework Convention on Climate Change which committed signatories to achieving a decrease in emissions of greenhouse gases.

Kyoto targets – the greenhouse gas reduction targets set under the Kyoto Protocol.

Launder – channel by which molten metal is transferred between vessels. (eg. furnace to ladle, ladle to mould).

Leakage – transfer of environmental impacts of industrial processes a country without mandatory environmental controls.

Lost foam process – a casting process whereby a sacrificial polymer foam pattern is used to form a cavity in a sand mould.

Melting loss – quantity of metal lost by oxidation and dross removal from molten metal.

Mould yield/die yield – the net weight of a trimmed casting as a proportion of that put into the mould/die.

Plant utilization – productive time expressed as a percentage of total available time. (eg. if a plant operates a ten hour shift, two hours of which is needed for job changeovers, the utilization would be 80%

Primary energy – Energy embodied in natural resources (e.g. fossil fuels, sunlight, uranium) that has not undergone any anthropogenic conversion or transformation.

Primary energy equivalent conversion factor – Electricity is a derived energy and for the purpose of comparison with fossil fuels in terms of carbon dioxide emissions is converted to primary energy using a delivered to primary conversion factor that accounts for the electricity generation mix. The current delivered electricity to primary conversion factor used here is 2.6 for the period 2000-2010. (ETSU, 1999b)

Rear exhaust – waste gas flue connected to the heating chamber of a gas-fired melting furnace as opposed exhausting waste gases from an open furnace top.

Revenue neutral - no net effect on the exchequer's annual revenue.

Scrap – castings rejected as non-conforming to specification.

Site energy – the total quantity of energy used in a production site.

***Small and medium sized enterprises** (SMEs)* – firms with fewer than 250 employees worldwide.

Specific energy consumption (SEC) – in manufacturing, is the amount of primary energy required to make a quantity of product. It is a process efficiency indicator. However, when assessing this on a site or sector basis, account must be taken of changing production – statistical energy data is only partially relevant when assessing changes in industrial efficiency.

Tonnes cast – quantity of metal poured into moulds.

Tonnes sold – weight of castings invoiced.

UK carbon dioxide emissions by source (Table 2.2) – quantified in millions of tonnes of carbon equivalent calculated by the ratio of the atomic weights of carbon and carbon dioxide, ie 12/44.

1.6 Delineation of scope

The research investigates the principal sources of greenhouse gases and the government's commitment to reduce greenhouse gas emissions as a whole and energy related carbon emissions of energy intensive industries in particular. The empirical research was focused on energy profiles within the aluminium casting sector.

The foundry industry, being energy intensive, is included in the discount arrangements of the existing climate change levy scheme. Even with the availability of discounts, the increased cost of energy and costs of meeting the agreed reduction in energy use will raise production costs. The challenge is meeting reduction targets without incurring increased costs.

The overall aim of the research was to investigate the options open to the foundry industry to meet the government's commitments and targets. Before looking into the energy related CO_2 emissions from foundries, it is necessary to investigate the principal sources of emissions for the UK in general and the potential for reducing them. This can be narrowed down to business as a whole with particular attention given to energy intensive industries. The detailed study concentrates on the cast metals sector – the focus being the aluminium sub-sector.

To achieve the aims, the research evaluates the problem of reducing energy-related carbon emissions from foundries, against the background of reductions in other sectors of the economy. Surveys within the aluminium casting sector were undertaken to establish energy profiles of companies and illicit views and opinions from practitioners.

Detailed studies were made of three representative companies to determine the energy used in the casting process and the potential for saving. Data obtained from the case studies were analysed and compared with other published data. From this, conclusions were formulated and implications for public policy are suggested.

A questionnaire and interviews were used to find how energy is utilized in aluminium foundries and general attitudes to improving efficiency. Case studies were undertaken to find how energy is used for melting and holding aluminium.

To achieve the overall aim, the research:

- evaluates the problem of foundry energy use within the context of reductions in other sectors of the economy;
- undertook a survey within the aluminium casting sector to establish the energy profiles of companies and illicit views and opinions;
- undertook surveys within three representative companies to determine the energy used in the casting process and the potential for energy saving;
- analysed the data obtained from the surveys and compared other published data;
- formulates conclusions and implications for the policy suggested.

1.7 Outline of the thesis

The next chapter covers the current sources of CO_2 emissions, the UK energy picture and government policy. The practical problems involved to mitigate the potential effects of global warming are discussed. The chapter deals with the climate change levy and issues associated with it.

Chapter 3 sets out the methodology adopted and reasons for its adoption. The structure of the spreadsheet model is explained and the procedures followed for the research are described.

The first part of Chapter 4 details the result of the surveys and experimental work. The findings are then analysed and the scope for energy saving measures is discussed. Potential reductions in SEC for the aluminium casting sector are estimated. The chapter concludes with a general review of the findings.

The final chapter of the thesis analyses the research and compares the findings with others' work. Based on the research findings, a spreadsheet model is used to test several postulations for the application of levies on business energy use. The hypothesis is evaluated against government targets and reviews the impacts on the industry's competitiveness. The broader implications for UK manufacturing and government policy are discussed. The final section proposes an alternative approach to encourage energy efficiency improvements in UK industries – an approach that could avoid the complexities and possible negative impacts of the existing strategy on energy intensive industries.

1.8 Summary

The global warming debate was summarized succinctly by Lindzen (2001) who said that members of the National Academy of Sciences (NAS) panel on climate change are not in a position to confidently attribute climate change to increased levels of atmospheric CO_2. NAS argues that the global climate is *always* changing – a millennium ago the Northern Hemisphere was in a warm period, three centuries ago it was emerging from a 'little ice age', and thirty years ago global *cooling* was a concern. Scientist are not certain what relations, if any, exist between global climate changes and water vapour, clouds, severe weather events, and other factors including regional climate changes. It is not possible to predict changes in the levels of greenhouse gases because they will depend upon economic and technological changes that cannot be predicted.

The *threat* of global warming from an enhanced greenhouse effect caused by increased levels of greenhouse gases in the earth's upper atmosphere, could be one of the biggest concerns for international governments for the foreseeable future. Global warming and its effects on the world's climate could cause both environmental and political crises in the coming years. It is an issue that was adopted by the United Nations, leading to the signing of the Kyoto Protocol in 1999. Together with other developed nations, member states of the European Union (EU) are taking a leading role in the response to the concern by committing to reduce greenhouse gas emissions.

The dichotomy of meeting increasing demands for energy and reducing the environmental impact of its production and use, presents a serious challenge to governments of developed countries. The question of whether or not the increasing combustion of fossil fuels is contributing to long-term global warming with the concomitant climate change is probably immaterial. The real issue may be an impending lack of sufficient fossil fuel reserves for sustainable development exacerbated by inefficient use today.

Chapter 2: The problem

2.1 UK commitments

In the previous chapter, the background to the problem of reducing energy consumption in the aluminium casting industry was examined from the perspective of the international community. In this chapter, the practical problem of meeting the government's emissions reduction targets and the impact on UK manufacturing will be examined. The discussion will focus on the issues raised by government policy and the ability of industry to deal with the effects.

If the government waits for energy prices to rise naturally influenced by market forces, time will be lost – time that is critical if the Government is to meet the targets that have been set. It is therefore imperative that the economic instruments available are applied as soon as possible; even now it would be two or three years before such measures had a significant effect on energy usage. It would be well into the decade before the effects will be significant, leaving less than ten years in which the targets are to be met.

The UK government's environmental objective is underpinned by its acceptance of the serious threat of climate change, its role in the Kyoto negotiations, commitment to the Kyoto targets and tougher domestic targets. Although the UK will be responsible for only 1.6% of global CO_2 emissions by 2010, the government has assumed an important role in the perceived long-term need for global cuts that may be as high as 60% below 1990 levels.

As its commitment to the Kyoto Protocol, the UK agreed to reduce its greenhouse gas emissions by 12½% below 1990 levels by 2008-2012. Since carbon dioxide is the most important of these gases, the government made a unilateral commitment to reduce specifically CO_2 emissions by 20% below 1990 levels by 2010. The combustion of fossil fuels is the greatest source of carbon emissions; reducing fossil fuel use is the most important step for meeting the targets.

The government expects all sectors of the economy to contribute to its carbon reduction strategy. The policy to change from coal to gas led to a large reduction of carbon emissions from the electricity generating industry. Economic instruments in the form of taxes and fuel duties, and regulation of vehicle emissions have been used to encourage fuel efficiency in the transport sector.

Although the government has only limited control over the UK economy, it can influence the cost of commodities such as fuels by imposing duties and levies. To meet its commitment to reducing greenhouse gas emissions, the government expects business, including energy intensive industries, to reduce its specific energy consumption. A levy on business energy use is intended to encourage this.

2.2 EU energy policies

To meet the EU and UK commitments to ecological concerns, legislation and other forms of coercion on industry and commercial organisations are unavoidable. The EU has accepted that global average temperatures should not exceed 2°C above pre-industrial levels to avoid major risks on eco-systems. To meet this target, it proposed that emissions by industrialized countries should be reduced in the long-term by at least 30% or even 55% compared to 1990.

The European Commission's 'Shared Analysis Project' (1999) concluded that the responsibility of the EU in energy policy matters would gain importance as a result of:

- long-term trends of increasing dependence on imported energy;
- the dynamics of the internal market;
- liberalisation of the energy markets;
- enlargement of the EU;
- concern about climate change; and
- globalisation of major industries.

According to the European Commission's (EC) report, some European countries have been slow to respond to demands for more 'creative' policy approaches to the environmental problem. However, the Kyoto Protocol has created a change of attitudes towards emissions trading and flexible mechanisms such as joint implementation. The UK government together with those of Denmark and Norway has taken the initiative by proposing a framework in which such a trading scheme could be introduced.

The EC's conclusion was that to be effective, the enaction of policies has to be complemented by high profile campaigns to increase public awareness of the issues. The long-term solution to environmental problems will depend upon informing people about the fragility of the eco-system.

Perhaps there is a hidden agenda embedded in EU energy policy. The commitments of the UK and other EU member states go beyond the Kyoto agreement. The control of global warming will reduce the risk of climate change and also conserve finite resources. The latter will bring long-term economic benefits by extending the time to depletion of valuable energy sources. For example, the UK's pledge to reduce CO_2 emissions specifically by 20% by the UK by 2010, and Germany's by 25% by 2005, will bring underlying economic and political benefits.

Timing is a key issue since there is likely to be a long delay between a reduction of emissions of GHGs and the stabilisation of atmospheric concentrations. The IPCC (1995) acknowledges that there will be societal time lags for raising public awareness, therefore the development and timing of policy actions will be crucial. The relatively slow turnover of energy-using capital goods also is likely to delay the effectiveness of policies.

The momentum gained by the debate so far must not be lost. A strong foundation has been created on which to build. The threat of global warming is a serious issue so that the commitments made need to be more than rhetorical. Energy use must be reduced without unacceptable costs on the economy. Energy policy presents difficult challenges not the least being to meet demand without imposing undue burdens on the environment.

2.2.1 UK energy policy

A mix of policies may be the most effective approach to reducing emissions. Policies must be acceptable not only for Organisation for Economic Co-operation and Development (OECD) countries, but must also avoid damaging relations between OECD and the rest of the world. The UK climate change levy and similar measures in other EU states are probably the first of a range of policies to cut carbon emissions by 20% over the current decade. Reducing the energy used by manufacturing industries will lead to lower production costs and lower output prices. This in turn should help economic growth without the risk of inflation.

An energy policy needs to be robust and should be designed to react slowly to short term changes such as world energy prices and variations in the national economy – but it is important that policies anticipate long-term changes as they are identified. The long-term results from policies to reduce carbon dioxide emissions may vary widely from any short term achievements.

It would seem that the UK's targets for the reduction of CO_2 emissions were set and evaluated before policies were designed. But there has been an inevitable time interval between the setting of targets and policy design. Therefore, there is a high risk of failure if goals are set without basic policy design and an integrated implementation strategy. Policy elements in isolation are likely to result only in partial success. By assessing the interactions between the components, the chance of success should increase. The gaps between components should be bridged by the strategies pursued.

Dutch energy policy focuses on the security of the supply of energy at competitive price levels, with the minimal negative effects on the environment. van Drehcht (1992) pointed out that government policies related to energy efficiency only have very limited effect on the actual use of energy and tangible signs of effects on efficiency depend on the *combined* reactions of energy users themselves. To attempt to quantify the effect of policy, it is important that energy users are categorized in manageably sized groups, (SMEs etc.), so that they may be targeted strategically.

But formulating government policies, making declarations, signing protocols and setting targets are relatively easy. It is much more difficult to formulate effective strategies and design initiatives to meet the desired objectives of reducing greenhouse gas emissions. To be successful commercially and socially, government environmental policies need to satisfy two conditions: the regulatory framework must apply equally to all and policies must be internally consistent. The UK government undoubtedly agrees but the conditions are not easy to meet. Deputy Prime Minister John Prescott (1998) warned that the government would introduce a complex mix of policies, environmental, social and economic. According to the Deputy Prime Minister, the aims of the government's overall policy are to achieve:

- social progress that recognizes everybody's needs;
- effective protection of the environment;
- prudent use of natural resources; and
- high and stable levels of economic growth and employment.

The three broad aims of the UK government's energy policy are – economic, political and environmental. Apart from meeting the policies and environmental aims, economic benefits will accrue from energy efficiency and conservation of indigenous fossil fuel reserves. Reducing the rate of extraction and use of fossil fuels will conserve reserves for future use when their value will be higher from scarcity. The government will not consider sequestration as an option – the aim is emissions reductions. Using energy more effectively will be good for business profits and the environment.

In the past, UK governments have not been specific nor have the strategies for the implementation of policies and their interacting components. Achievements for energy efficiency, whilst worthwhile, may not have been as good as they might have been had there been a better response from energy users. In recent times, a lack of coherent government energy policy on energy pricing has undoubtedly led to flagrant energy waste.

The present balances of fuels for UK electricity generation are – 39% gas, 31% coal and 21% nuclear. (DTI, 2001) Many energy professionals believe that the optimum mix is 30%

gas, 30% coal, 30% nuclear and 10% renewables. However, recent trends indicate that gas could account for as much as 80% by 2010, which would mean that the UK economy would be reliant upon gas for the majority of its non-transport energy needs. This would conflict with the government's priority for a diverse, safe and secure supply of energy. To meet this priority and at the same time reduce energy related carbon emissions is a formidable task.

The UK government and its agencies should be *seen* to support the policy for emissions reductions. The issues need to be debated more widely to raise public awareness and gain public support. A broad debate on energy supplies and efficiency is needed if policy objectives are to be met. The Cabinet Office Performance and Innovation Unit (PIU) was set up recently for such a purpose.

Green Alliance (1999), suggested that one way forward might be the creation of a 'sustainable energy agency' by merging the many organisations currently responsible for policy advice, and supporting 'green' energy initiatives. Such an agency may provide the synergies that are presently lacking. (This is discussed more fully in Chapter 5).

The government's firm stance on CO_2 emissions reduction might lead to a sustainable energy policy framework for the UK. In 1998, the moratorium on gas-fired power stations and the declaration to preserve a market for at least 20 million tonnes of coal per year indicated that the government was developing an energy policy. However, this was brought into question when in 2000, the ban on new gas-fired generators was lifted and six new gas-fired power stations were approved. As a result of the recent turmoil in the energy markets, there is some doubt about the timing of these projects. High gas prices in the early part of 2001, led to the shutdown of some combined cycle gas turbine plants, and putting standby coal and oil-fired stations into operation.

It is important to demonstrate that the UK is not alone in its commitments to combat the possible effects from global warming on the world's populations. UK policy makers should refer to the positive strategies of other nations such as Japan and other European states such as the Netherlands and Denmark. For example, the Netherlands' energy efficiency programme is supported through a range of measures. Long-term Agreements (LTAs) with industry set targets for efficiency improvements and CO_2 reductions. Energy-intensive industry is exempted from higher energy taxes if it agrees to 'challenging' LTAs. The energy intensive sector also receives support through R&D, pilot project grants, and tax credits up to 40 per cent for efficiency investments. This is funded by an energy tax introduced in 1996. The Netherlands also has an enhanced capital allowances scheme whereby investment in energy efficient technologies qualify for 100% tax allowance against profits gained in the year of the investment.

The Netherlands' Memorandum on Energy Conservation (van Drehcht, 1992) set five categories of measures intended to enable the Netherlands achieve its targets:

- information;
- regulation;
- agreements;
- subsidies to apply energy-saving techniques;
- technological development.

van Drehcht stresses that each category has its own characteristics and strengths that must justify any side effects they may evoke.

The dramatic rise in gas prices for business users in the latter part of 2000 has eroded the one competitive advantage UK firms had over their counterparts elsewhere in Europe.

Cheaper gas had to some extent mitigated the adverse impact of the sterling/euro exchange rate, and would have lessened the financial impact of the UK Climate Change Levy (CCL).

In addition to the UK losing the advantage of low gas prices, in the last quarter of 2000 and the first quarter of 2001, industrial gas consumers on the continent had appreciably cheaper spot prices than their UK competitors. The UK forward daily price (for daily purchases one month in advance) rose from 21.3p a therm in September/October 2000 to 25.3p a therm in October/November and 28.4p a therm in November/December, compared to a quarterly average of 22.8p. Long-term contract prices are now similar throughout Europe.

If energy prices rise as a result of market pressures, then smaller oil and gas deposits, and those that are more difficult to extract will become viable. However, if indigenous fossil fuel resources continue to be used at the present rate and prices remain relatively low, the economically viable deposits of gas and oil will run out. The UK and EU then will be dependent on imports from Russia, North Africa and the Arabian Gulf for example. There is a powerful strategic case for conserving indigenous resources to match the gradual change to alternative energy sources.

In addition to the economic benefit of energy conservation, there would be a strategic value in the event of political turmoil in any of the principal oil and gas producing regions such as the Arabian Gulf and Eastern Europe The UK government's energy policy obligation is to ensure the availability of diverse, sustainable supplies of energy that will satisfy the needs of all, including industrial and commercial users. At the same time, the government has to meet its *environmental, social and security of supply* objectives.

At present, the UK is 'energy rich' with ample indigenous supplies of coal, gas and oil, and diverse electricity supplies generated from gas, coal and nuclear energy. Security of supplies has not been an issue. This is likely to change. Gas imports are projected to increase. By the end of 2002, UK demand is expected to outstrip supply. By 2006, the UK could be importing up to 15% of its gas needs compared to 2% in 2001. (Cabinet Office Paper, 2001). According to Walker (2001), gas imports could rise to 70% by 2030. The UK is likely to be a net oil importer as early as 2006/7 and by 2010 there could be significant imports of coal and gas. If these forecasts are correct, security of supply will become an important consideration. These factors reinforce the future importance of renewable energy and energy efficiency.

Although the government's overriding energy policy is *"to ensure secure, diverse and sustainable supplies of energy at competitive prices"*, (DTI, 1999a), there is little evidence that the UK has had a coherent energy policy for many years. This may be as a result of conspicuous circumstances such as the various fuel crises in the latter half of the last century, and the availability of ample indigenous sources of coal, oil and natural gas. The government's aim of improved energy efficiency may not be achieved without cogent policy objectives, and specific targets for energy efficiency and measures designed to achieve the objectives.

To meet its climate change commitments, the government has set out a framework based on three main tools – targets, incentives and financial support. *Targets* have been set for emissions reductions, and contributions from CHP and renewable sources. *Incentives* include taxation (climate change levy), regulation through the forthcoming utilities act (renewables obligation and energy efficiency commitment for energy suppliers), and emissions trading. *Financial support* includes recycling part of the climate change levies as capital grants, R & D funding and additional support for new technologies.

2.3 *Current sources of greenhouse gases*

It is around 250 years since the beginning of the Industrial Revolution. To reduce the accumulation of the atmospheric level of CO_2 to pre-Industrial Revolution conditions would require revolutionary technologies. It will take many years to develop the technologies and decades to implement them.

It is impractical and unacceptable to concentrate solely on the environment at the expense of future economic growth. Economic growth not only increases the burden on the environment – it also provides conditions necessary to protect the environment by making it possible to support the costs of environmental protection. Environmental protection and economic growth are interrelated concepts of sustainable development.

It seems certain that fossil fuels will be the principal source of energy for economic development in the next decades. The sources of fossil fuels are stable and their extraction is economically favourable. Measures to restrict the use of fossil fuels for environmental reasons could impede economic development and the overall availability of energy. There is no immediate solution to the associated rise in greenhouse gas emissions, and any action may take two decades to be effective.

Humankind has depended on fossil fuels in its quest for ever-increasing amounts of energy to meet the demands of a rapidly growing world economy. Growing carbon dioxide emissions are an inevitable by-product. However, at the present time – with limited supplies of renewable energy – economic development cannot be enjoyed without the associated emissions of CO_2.

The principal greenhouse gases are carbon dioxide, methane, nitrous oxide, ozone, CFCs, and water vapour. Carbon dioxide accounts for about 70% of the human-induced increase of greenhouse gas concentrations in the upper atmosphere. The relative warming potentials of the gases are shown in Table 2.1. Methane, which occurs naturally from living organisms, contributes 20% but has 20 times the warming potential of carbon dioxide. The third most important anthropogenic greenhouse gas is nitrous oxide, a by-product of combustion, the warming potential of which is 200 times that of CO_2.

Table 2.1. ***Summary of the principal gases associated with global warming.***

Gas	CO_2	CH_4	N_2O	CFCs	O_3
Sources	Fossil fuel burning, soil destruction	Livestock, rice paddies, gas leaks, landfill	Fuel burning, agriculture	Refrigeration, air conditioning, foam blowing, aerosol propellants	Photochemical processes in the troposphere
Sinks	Oceans, biosphere	Reaction, soil uptake	No tropospheric sink. Degradation in stratosphere		Chemical reaction
Typical tropospheric concentration/ mg m^{-3}	678	1.1	0.61	–	0.04-0.20
Climatic effect of one molecule relative to CO_2	1	20	200	10,000	2000

Source: Barratt *(Chemistry in Britain, 1992)*

The annual input of CO_2 to the atmosphere is in the order of 6 billion tonnes, but atmospheric CO_2 increases only by about 2.5 billion tonnes per year. The balance is distributed to the oceans, to terrestrial biota and possibly to other sinks as yet unidentified by scientists. Although the oceans are thought to absorb about 2.5 billion tonnes of CO_2 per year, according to Kemp (1994) recent studies suggest that the actual total absorption may be only half of that amount. The destination of the remainder has important implications for the study of the enhanced greenhouse effect and continues to be investigated.

Fossil fuel use contributes more than two-thirds of all anthropogenic sources of CO_2 which Nakićenović (1997:272) puts at about 20 gigatonnes per annum. Emissions of GHGs are unavoidable by-products of fossil fuel combustion, therefore without an abatement strategy, these will inevitably rise with economic growth.

According to Nakićenović, during the last two centuries, global consumption of primary energy has increased about 2% per year, doubling on average every 35 years. As a result, CO_2 emissions from energy use have also increased. This trend is expected to continue at least at this annual rate and 90% of world primary energy is likely to be fossil fuel derived until mid-century. (European Energy Outlook – 2020, 1999) As discussed in Chapter 1, the other principal sources of CO_2 arise from clearing of vegetation by burning, decay of biomass and increased rate of oxidation of newly exposed soil.

In the period 1980 to 1990 the total global GHG emissions increased by 15%, mostly due to a growth of CO_2 emissions in the less industrialized countries. In the early 1990s, global CO_2 emissions did not increase, mainly as a result of the world economic recession and restructuring in the Central and Eastern European Countries (CEEC) and Commonwealth of Independent States (CIS).

Okamatsu (1993) presents an analysis of total CO_2 emissions in 1987 expressed in weight of carbon. It showed that advanced industrialized countries generated 2.7 billion tonnes, the former Soviet Union and the Eastern Bloc generated 2.1 billion tonnes, and the developing countries generated 1.2 billion tonnes, totalling 6.0 billion tonnes. This equates to 3.3 tonnes per capita per year in the advanced industrialized countries, compared to 1.4 tonnes and 0.5 tonnes respectively for Eastern European and developing countries. Based on the current trends for population growth, Okamatsu predicts that in the second half of the 21st century, the advanced industrial countries will have a population of 900 million, the former Eastern Bloc – 2.3 billion and the developing countries – 6.8 billion. Assuming that the per capita emissions remain unchanged for the advanced countries, while increasing by 50% and 100% respectively in the Eastern Bloc and developing countries, the total annual global emissions of CO_2 would amount to 14.2 billion tonnes. The developing countries alone would account for 6.2 billion tonnes which would exceed the world total in 1987.

2.3.1 UK sources of CO_2 emissions

At the European level, EU member states reduced the emissions of the basket of six greenhouse gases by 4% between 1990 and 1999 and total CO_2 emissions from the EU fell by 2% between 1990 and 1994. (EEA, 1998) Most of these reductions were due mainly to short term factors such as a decline in industrial activity, reduced rates of economic growth, the restructuring of Germany, closure of coal mines in the UK, and the conversion of power generation to natural gas.

Between 1990 and 1997, emissions of the basket of six greenhouse gases fell by 9% and provisional estimates for 1998 showed that the trend continued. Most of the reduction was due to the demise of heavy industry, the switch to gas for electricity generation, combined cycle gas turbine (CCGT) generators, and combined heat and power (CHP) installations. Government figures published in May 1999 indicated that the UK was on course to meet its international commitments to reduce emissions of greenhouse gases. Walker (2001) estimates that if the UK meets its targets, then it will be responsible for only 1.6% of global CO_2 emissions by 2010.

From the early 1970s, energy intensity, (energy consumption per unit of GDP) in the UK has decreased, mainly due to energy efficiency improvements and changes in the overall structure of the economy. However, between 1980 and 1992, total gross energy consumption increased by about 1% per year and then stabilized. This is unlikely to change, due to major underlying factors such as low energy prices (that discourage energy conservation measures), and increased energy use in transport. The latter has cancelled out gains made by industry. Efforts to reduce energy consumption and emissions from transport will take time to be effective. Other sectors with shorter response times have been targeted for efficiency improvement.

Between 1997 and 1998, emissions from power stations rose slightly due to increased use of coal, caused by reduced availability of imported electricity from France and the lower availability of some gas-fired and nuclear stations in the UK, during maintenance and repair.

Table 2.2. ***UK carbon dioxide emissions by source expressed as million tonnes of carbon, 1970 to 2001.***

Million tonnes of carbon

Year	*1970*	*1980*	*1990*	*1999*	*2000*	*2001**
Power stations	57	58	54	39	42	44
Industrial combustion	67	43	38	38	37	37
Domestic	26	23	22	23	23	24
Transport	22	26	32	34	34	34
Other sectors	13	14	19	17	16	16
Total	185	164	165	151	152	154

* Provisional figures
Source: DEFRA (*Energy Trends, 2001*)

Table 2.2 shows that in 2000, electricity generation accounted for 28% of UK carbon emissions. Improvements in the sector will be essential to make a substantial contribution for meeting the UK's commitments. Although there has been a general reduction trend in UK carbon emissions due to the substitution from coal to gas for electricity generation, the DTI estimates that there was an emissions increase of 2% in 2000, and between 2000 and 2001 a further increase of 1.5%. The trend reversal was influenced by a further fall in nuclear electricity generation, non-availability of nuclear and combined cycle gas turbine power stations during repair and maintenance, and higher gas prices at the end of the year when more coal was used.

At 148 million tonnes, the UK's net carbon dioxide emissions in 2000 were 7% below 1990 level, (DTI, 2001) However, the increase in 2001 means that emissions are now only 6% below 1990 level but this is encouraging and indicates that the 12.5% GHG reduction target by 2010 accepted under the Kyoto agreement *should be* achievable. However, assuming that there is some growth in GDP, to meet the 20% reduction target will require a pragmatic position by the government to encourage greater energy efficiency, renewable power generation, and to implement an integrated transport policy.

Table 2.3. ***Carbon Emissions per Unit of Delivered Electricity Attributed to ESI Generation used in the ETSU GAD Work.***

Year	kg C/GJ	kg CO_2/GJ
1990	60.7	222.7
1991	58.2	213.3
1992	52.5	192.5
1993	46.2	169.5
1994	44.6	163.6
1995	43.9	160.9
1996	42.0	154.1
1997	38.2	140.2
2000*	31.7	116.3
2005*	35.9	131.7
2010*	31.8	116.7
2020*	36.1	132.4

*Projected – Final figures are yet to be published (Jan. 2002)
Source: Global Atmosphere Division (GAD) of DEFRA [NA(99)30]

Table 2.3 shows that between 1990 and 1997, the electricity supply industry (ESI) in the UK reduced its carbon emissions by 37%, exceeding the total UK commitment made at the Rio de Janeiro Summit in 1992. The reduction was made mainly by switching from coal to gas, and by increasing the efficiency of generation. But the fuel switch gave only a one-off benefit for the ESI, so there is now a continuing need for generation that does *not* emit greenhouse gases. To meet this demand the DTI has set a target of generating 10% of the UK's energy from renewables by 2010.

2.3.2 CO_2 emissions due to energy use in UK industry & foundries

The UK's CO_2 emissions in 1990 were 167m tonnes. In 2000, this fell to 148m tonnes. (Table 2.2). On a business as usual basis 32m tonnes of the reduction was attributable to the industrial sector, representing approximately 20% of the total.

Domestic and transport account for 40% of total CO_2 emissions. But energy use in these sectors must be dealt with stealthily to avoid adverse reactions such as the road fuel protests of September 2000. Emissions from the increasing use of private transport are a complex issue, but without some actions to reduce them, emissions reductions from industry could be nullified by the increasing use of cars. However, that does not reduce the importance of energy efficiency in UK industry. Industry can make a significant contribution to emissions reduction and in doing so improve its competitiveness in global markets.

The UK's total final energy consumption in 2000 was 160.1 Mtoe of which 36.2 Mtoe (23%) was used by industry. To put this into context, according to ETSU (2000), UK foundries use around 1.6 GWh of primary energy (GWh_p), for melting to produce approximately 200,000 tonnes of aluminium castings. 1.6 GWh_p is equivalent to approximately 138,000 toe which is 0.4% of the total used by industry. On this basis, 128,000 tonnes of carbon are emitted annually from energy used for the production of aluminium castings.

The mix of delivered energy used in aluminium foundries (ETSU, 2000), was 34.2% electricity, 63.2% gas, the balance being oil and propane. Assuming that the mix of final energy used is unchanged and applying the current delivered to primary energy conversion factor of 2.6 to electricity (ETSU, 1999), 57.5% of the primary energy used is electricity, 40.8% gas, and 1.7% oil and propane. Using the derived carbon emissions factors (ETSU 1999), the aluminium casting sector carbon emission was 120,000 tonnes per annum, (439,000 tCO_2). This agrees with the later ETSU emissions estimate.

2.3.3 Scope for reduction of CO_2 emissions attributable to industry

According to ETSU, if 'all cost effective' (ACE) technologies were adopted by industry, the annual reduction in CO_2 emissions from current levels would be 19 per cent by 2010, equivalent to 24.2 million tonnes CO_2. Also, it is estimated that some industries, such as car manufacturing, could achieve CO_2 emissions reductions of nearly 50 per cent by 2010 if they used 'all technically possible' (ATP), emission reduction technologies. There has been neither policy nor financial support to capture this potential, apart from information available through the government's Energy Efficiency Best Practice Programme (EEBPP).

In 2000, energy related greenhouse gas emissions from the UK manufacturing sector were 2.5% below 1990 levels even though total output for the sectors covered increased by 11% in real value. (DTI, 2001) According to ETSU, industry should meet an 8% reduction target by 2010 if it continues with 'business as usual' (BAU), will not quite meet a 15% target by 2010, but will certainly not meet the 20% target without additional measures. ETSU projections for industrial CO_2 emissions (Table 2.4.) indicate that energy efficiency measures should have been adopted earlier if reduction targets are to be met.

Table 2.4. *UK industrial sector carbon emissions.*

	Million Tonnes of Carbon				
	1990	1995	*2000*	*2010*	*2020*
Reference baseline	42.3	35.4			
Base year for projections					
Business as usual			*32.3*	*33.1*	*36.0*
All technically possible			*22.2*	*23.1*	*25.7*

Source: ETSU, 2000

ETSU (1998b) forecast that emissions would to grow in papermaking, plastics and electrical engineering. Emissions attributable to energy used by the chemical, iron & steel, and non-ferrous metals sectors are expected to fall. The reduction quoted for the non-ferrous metals sector is 49%, much of which will be as a result of plant closures; but then the sector's emissions are expected to increase in the 20 years between 2000 and 2020. Only 22% of industry's reductions will be attributable to energy efficiency measures – including the net effect of CHP. Most of the reductions will be due to changes in electricity generation

2.4 UK electricity generation

According to Walker (2001), the reduction of the nuclear contribution to the UK's power generation by 2010 will make it very difficult for the government to achieve its target of a 20% reduction in emissions of CO_2. UK nuclear generated power will reduce from a peak of 32% of capacity in 1997 to 7% by 2010, and virtually zero by 2020. If this lost capacity is replaced by gas-fired generation, the net impact on CO_2 emissions will be an additional 4m tonnes per year and double that if it is substituted by coal.

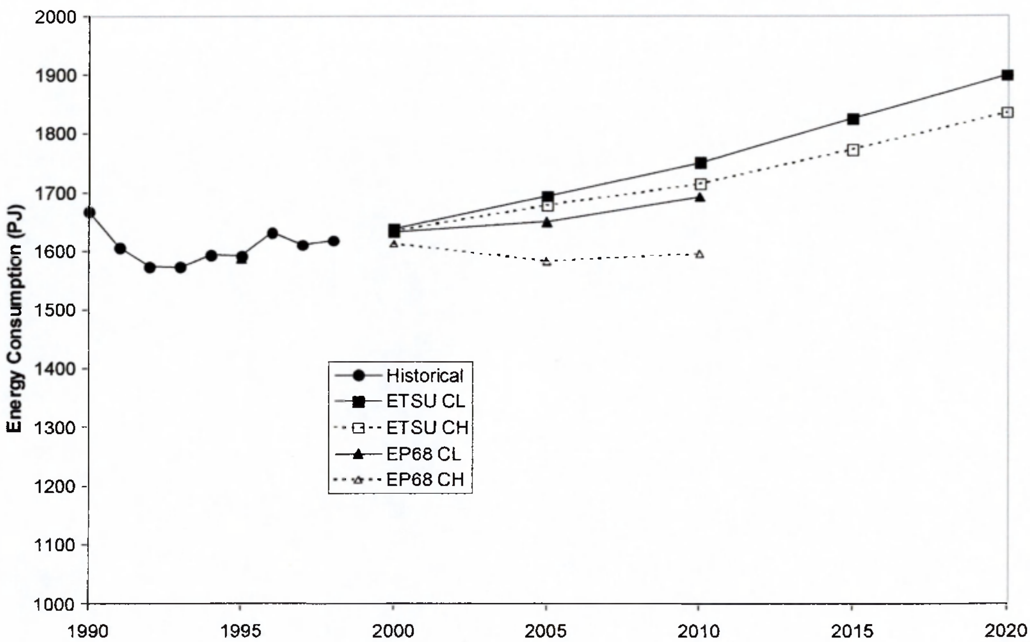


Figure 2.1. ***Energy consumption projections for high and low fuel price scenarios – 2000-2020.***
Source: DETR, 2000

Electricity demand is increasing and is expected to continue to increase in the foreseeable future by 1-2% per annum. (Figure 2.1) Although higher contributions from renewable resources are planned, these may not be sufficient to offset the environmental effects of the increased demand for electricity. It follows that atmospheric pollution from non-renewable energy sources could be dominant for the foreseeable future.

2.4.1 Renewable energy

In 1997, renewable energy accounted for 5% of the total energy used in the EU. A European White Paper (Environment Information Bulletin, 1998) on renewable energy, proposed that the target for the renewable share of the energy market by 2010 should be raised from 6% to 12%. If achieved, this could reduce EU CO_2 emissions by 5%. The renewable energy targets for individual member states are political commitments and are not legally binding. The UK government's target is 10% of electricity from renewable sources by 2010. If this target is met, it should offset the environmental effects of the forecast increased energy demands to meet economic growth.

To encourage development of renewable energy, a Fossil Fuel Levy was introduced in the UK in February 2000. The levy replaced the Non-Fossil Fuel Obligation (NFFO) that was intended to provide market support for the nuclear industry, and ensure a guaranteed price and market for other non-fossil fuels under the 1998 Electricity Act. The Fossil Fuel Levy, applied to all electricity sales, was originally set at 0.7% in England and Wales and 0.8% in Scotland. The rate was reduced to 0.3% and will be zero from April 1 2002. OFGEM (the electricity regulator), expects there to be sufficient funds to make up the difference between the payments guaranteed to renewable electricity generators and the price they can sell their power to the market. (DEFRA, 2002)

Electricity suppliers are obliged to obtain 5% from renewable sources by 2003 and 10% by 2010. Putting the obligation into context, in 2000, 2.8% of the total electricity used in the UK was from renewable sources. At approximately 3 TWh, it was treble that in 1990. Bio-energy accounted for 82.0% of renewable energy, large-scale hydro was 15.0% and wind 2.5%. Wind-generation is expected to grow rapidly in the next two decades. To meet the DTI's expectation that about half of the 10% renewable target should come from wind – 2.6% from onshore, 1.8% from offshore This will require about 2,600MW of capacity, or about 5000 0.5MW wind turbines.

Biomass is an important renewable energy source because the carbon dioxide emitted when it is burned has recently been taken out of the atmosphere by the plants making up the fuel. Provided that the fuel is not used more quickly than it can be produced, no more carbon is put into the atmosphere than is taken out. Depending upon the development of wind and wave power, projects that rely on coppice fuel, landfill gas, and municipal and industrial waste, could account eventually for up to 20% of the total renewable supplies.

The UK government's commitment to the Kyoto Protocol and the unilateral pledge to reduce CO_2 emissions by 20% of 1990 levels by 2010, seem unlikely to be satisfied by initiatives to alter the *behaviour* of energy users or by renewable energy schemes. The government may have regarded availability of sustainable energy as a secondary issue compared to the supply and use of fossil fuels, even though the renewable energy sector is growing rapidly. Walker (2001) expects renewable energy to make a valuable contribution to the reduction of carbon emissions. However, renewable capacity will be limited, capital intensive and will require embedded energy storage technology to be developed to supplement supply when output is low from wind, wave or tidal sources.

2.4.2 Combined heat and power

When electricity is generated in the conventional way in thermal power stations burning fossil fuels, only about one third of the input energy is converted into electricity. The balance of the energy is dissipated as waste heat via the cooling systems. There are further losses in the electrical distribution network. Combined heat and power (CHP) is the simultaneous production of electricity and useable heat from a single plant in a cost-effective and environmentally sound way. CHP systems generate electricity locally to the point of use, and use the heat generated to provide steam, hot water space heating and refrigerative cooling using absorption chillers. Approximately 40% of the energy is converted to electricity. Efficiencies around 80% are usual for 'good quality' CHP installations. This is very attractive, but CHP is not economically viable unless there is a demand for relatively large quantities of low temperature process heat for at least 4,000 hours per year. Therefore, the viability of CHP in terms of energy efficiency (as opposed to cost benefits) depends on the project being properly sized to meet the on-site or nearby heat and electricity requirements. CHP equipment suppliers claim that for every megawatt of effective energy (MW_e) produced by 'good quality' CHP, carbon emissions are reduced by 1,250 tonnes a year. (Alstom, 1998)

The European Commission (1998) set a target to double the then current market penetration of CHP to 18% by 2010. This is to be achieved by the introduction of tax and financial incentives, boosting the share of funding for CHP in existing EU programmes, and promoting agreements with industrial sectors.

For its part, the UK has a target of 5000 MW_e of CHP capacity by 2000. This was set back by the doubling of bulk gas prices in the latter part of 2000 and early 2001, so the original target is unlikely to be met until 2002 at the earliest. As part of the climate change programme, a new target of 10,000 MW_e of CHP by 2010 has been set.

2.4.3 Nuclear energy

The combination of improved energy efficiency, conservation and renewable energy may not meet the needs of environmental protection while providing a secure supply of electricity. There is a growing consensus that the UK cannot meet its environmental and resource responsibilities without 30% carbon-free electricity generation – that means renewable *and* nuclear. Baker (1999) said that the Royal Society and the Royal Academy of Engineering, supported unequivocally nuclear power generation. Baker believes that renewable energy sources are unlikely to make a significant contribution to the increasing demand for energy.

Reducing the emissions of greenhouse gases from energy use may be a priority of developed economies, but without alternative sources, there could be a serious shortfall in energy supply. The UK's share of the EU's 8% greenhouse gas emissions reduction under Kyoto may well be achievable – but nuclear power cannot be ignored if the government is to meet its commitment to reduce CO_2 and at the same time meet energy demand.

Many believe that global warming cannot be averted without a commitment to nuclear power stations – in the developed *and* developing economies. At the European level, the European Commission warns that without a significant component of nuclear power generation in the EU plant mix, achievement – or maintenance of a substantial CO_2 reduction on the 1990 level in the period after 2015 appears very difficult. It is likely that reduction targets for EU greenhouse gas emissions will become even more demanding. Recent studies indicate that to maintain nuclear energy's share of generating capacity to reduce emissions from fossil fuels will require the equivalent of 80 new nuclear plants to be built across Europe. (Ramsell, 2000)

The authors of the Shared Analysis Report (1999) forecast that nuclear generating capacity in the EU will increase to 181 GW by 2020 and to 212 GW by 2030. In the long term, Britain, like other developed countries, may have to resort to nuclear power – but this will need bold leadership from a well-informed, pragmatic government. Otherwise, the UK, like many other countries may find it impossible to meet electricity demand while complying with limits on greenhouse gas emissions.

It is uncertain if renewable energy sources will make a significant contribution to the increasing demand for energy. Non-emitting technologies such as advanced nuclear, solar or biomass may be available but not until towards the middle of the century. Nuclear energy has been debated for many years but it remains an anathema. If this scenario prevails, then atmospheric pollution from non-renewable energy sources will be a dominant issue for the foreseeable future – unless there is immediate action to curb the rate of energy use.

Those against nuclear energy have held the moral high ground. Politicians and institutions have avoided the topic as a politically sensitive issue. Battle (1998) when energy minister at the DETR, said that the government had not put a stop on nuclear power stations – the *people and planners* had. Walker (1998) stated that there must be a move from fossil to non-fossil – preferably nuclear where allowed. If adverse climate changes do occur, nuclear power could provide a short-term alternative energy source until other large-scale renewable technologies are available.

In June 2001, Brian Wilson, UK energy minister said that the government will need to assess what role the nuclear industry should play in meeting the government's security of supply and environmental objectives. *(Financial Times, June 26, 2001, p. 1)* It may be time for the debate to be open, and the public to face the realities of meeting the national objectives for safe, secure, diverse and competitively priced energy, to satisfy the ever-increasing expectations for living standards.

2.5 Attitudes and initiatives

2.5.1 Attitudes to environmental issues

The quality of life on earth today is to some extent a result of the ingenuity of our predecessors. In the same way, the quality of life of future generations depends greatly on mankind's activities today, which is conditional upon the acceptance of the responsibility to future generations.

Humans, being free, are able to do as they wish. In general, people are not concerned about things that do not directly concern themselves, but they should accept the consequences of their actions. People should not, nor indeed *cannot* dictate or determine the way future generations may live, but they should provide a safe foundation on which future generations can build their own ways of life. The argument has grown that humans are stewards of the earth and should discharge the responsibilities of that stewardship by responding to all warnings of threats to the earth's ecological balance.

One of the basic philosophies of modern economics is that humans must strive to make more and consume more. If the obsession with growth continues, advanced nations must develop and promote innovative, energy efficient technologies so that the developing world has the benefits of energy use to meet the growing expectations of their populations without putting undue stress on the earth's finely balanced ecosystems.

Ethics of sustainability

The problem of climate change is in reality a moral one. Therefore, approaches must be used to bridge the gap between the level of moral response to the issues, and that which is needed urgently to deal with the potential problem of climate change and its consequential effects.

Ethical attitudes to ecological issues can be likened possibly to attitudes to religion – there are those who are sincere and accept the laws on which their religion is based and conscientiously worship in their chosen way. On the other hand, there are those whose self interests drive them to do only things that will be of some direct benefit to themselves.

There must be some for whom the fundamental philosophies of religious teaching are beyond their capacity for comprehension; but in such cases, faith can replace understanding. There are those, probably the majority, for whom real understanding of ecological issues is impossible and therefore they must have 'blind faith' in the exhortations of those who *do* understand. There may be an analogy in environmental ethics. But faith can only grow in those who are fed with the essential teaching from those who are capable of expressing the need for responsible actions from present generations for the sustainable development of the earth.

Protection of the environment should be a compromise that is acceptable to meet the needs of mankind today but with consideration for future generations. Due to ignorance, this was not so in former times. In the past, there was very little interest in the principles of sustainability and the underlying ethics of the philosophy. There are those who do not consider climate change to be a phenomenon that could affect mankind today and probably will not do so in the future – in any case, they may simply feel that it is someone else's problem and there is nothing that they as individuals can do about it.

Unless people are personally committed to green concerns on ethical grounds there is likely to be unacceptably slow reaction to address the problems. A sense of responsibility to others must be nurtured in the developed populations so that they are seen to behave in a responsible way. Many understand environmental issues but are indifferent towards them. Environmental protection initiatives must be diverse to reach all, but it can be argued that it is essential that those with the ability to influence the behaviour of others should be foremost targets for initiatives. To be most effective, government propaganda should aim to influence the behaviour of all, but to be effective, the information must be lucid to all levels of intellect and intelligence.

It is more difficult to influence individuals than groups of people in organisations. It is easier to apply legislative pressure to companies. Businesses are usually conscious of their public image and influenced by stakeholders. Senior managers in companies are in strong positions to generate interest and action within their organisations; such influence can permeate organisations and their external environments through employees, suppliers, customers and the general public. Those who comprehend the issues must be encouraged to accept the responsibility with which they are charged by appealing to their altruistic sensitivity. Otherwise, there will be no alternative to tougher legislation.

Apathy

It is necessary to confront the past and respond accordingly to make corrections where possible on all global environmental issues, but as in all ethical or moral arguments, there may be people who simply do not care about the environment. Some may have reasoned arguments to support their attitude and simply disagree that there are potential problems from increasing levels of greenhouse gas emissions. There are people for whom global warming is not a pressing issue and that if it is occurring, by the time it reaches a critical phase, future generations or nature will have solved the problem.

Some are not aware of the connection between global warming and energy use. For example, one interviewee from the foundry industry said naïvely, 'using electric furnaces is as green as we can get'. Many do not understand or do not care about sustainable development and cannot understand the concern for the ecological impacts of industrialization by previous generations.

It is probable that many do not think that their individual contributions to the reduction of energy use is essential if progress is to be made towards meeting the internationally agreed targets for reducing greenhouse gas emissions. The apparent lack of understanding may be due to two factors – the misconception that a responsible attitude of a single individual is not significant to warrant any effort, and the other may be due to self interest since the problem may be seen as a long term one and will not directly affect the present generations. If this is so, such people need to be made more aware of the necessity for *all* to respond to the need for reducing all forms of waste – indeed such co-operation and involvement is crucial if progress is to be made towards sustainable development and reducing environmental damage.

Interviews undertaken for this research (Chapter 4) suggest that there is a great deal of indifference towards environmental issues in many sectors of industry (particularly in SMEs), and the public in general. This apathetic attitude stifles people's ability to act. Some companies admitted that they paid merely 'lip service' to environmental matters and only acted when forced to do so by either legislation or the risk of economic disadvantage.

One frequent argument is that investing time and money in energy saving and other related environmental programmes does not directly benefit business in the short-term. Baylis *et al.,* (1997) found that 55% of SMEs and 51% of large companies agreed that concern for the environment might be a question of *long-term* survival but actions must not reduce profits in the shorter term.

Several technical managers claimed they were too busy dealing with more pressing matters that make a direct contribution to the welfare of the business rather than deal with environmental matters. Such people often have authority and ability either to initiate or implement energy saving schemes. Since the associated costs are overheads they either reduce profits or price competitiveness. Unless competitors are committed also, there is not a 'level playing field'. Understandably, the majority of companies are concerned that their competitors should have the same environmental cost burdens.

2.5.2 Initiatives

ETSU (1998a) found that many organisations identified lack of awareness, or staff apathy as the greatest barriers to energy efficiency and environmental improvement. Experience showed that most employees are unaware of the amount of energy they are using, and often wasting, and consequently, have little motivation to make reductions. Therefore, improving awareness of energy usage and its waste is a major factor in changing attitudes that could bring significant savings for a relatively small investment.

The government itself cannot achieve targets for reducing CO_2 emissions. There must be commitment from all sectors of society, not the least from those employed in industry. But there appears to be considerable indifference to reducing energy use and the potential impacts of global warming. Consequently, there have been limited responses to energy efficiency programmes.

At a personal level, most of those interviewed during this research expressed a positive attitude towards environmental issues, but some did not feel that their personal contribution to environmental improvement programmes within a company could be significant. This suggests that more emphasis should be put on commitment at an individual level, supported by strong management to enforce environmental policies and schemes for energy efficiency.

Other ways will be needed to encourage producers and consumers to improve energy efficiency – through market pull programmes, integrated resource planning, demand-side management, financing, and partnerships between governments, NGOs and business. Otherwise, energy inefficiency could restrain economic growth. UK electricity generators claim that most of the energy efficiencies at the supply end have already been exploited. Therefore, further energy efficiency improvements can now only come from end users.

Government agencies have to increase knowledge and awareness of people by education. Prescott (1998:4) attempted to initiate this by inviting *everyone* to make a major contribution to the government's strategy for a more sustainable country and asked people to express their views on how this can be achieved. Prescott said that the old 'environment versus economy' clash is no longer constructive and that a more constructive one will improve the UK's economic performance.

Government information programmes have been based on objective and unbiased literature, with advice on energy efficiency investments. The current programme – the Energy Efficiency Best Practice Programme (EEBPP) – has been running since 1989, and according to ETSU (1999), the programme is on target to have stimulated savings equivalent to over 3 million tonnes of carbon per year. Whilst any level of emissions reduction is acceptable, this is well short of the savings that are required.

EEBPP promotional information for industrial energy efficiency campaigns, gives the impression that the only benefit is cost saving and does not stress the need for energy efficiency to benefit the Earth's environment and sustainability. In the past, there were few references to the government's commitment to reducing energy use in order to reduce GHG emissions. Slogans such as "More and more companies are realising that savings on energy bills impact bottom line profits....," and "There has never been a better time to put energy management at the top of the company agenda – and increase profitability," are typical.

The limited success may be a result of the emphasis that has been placed on the economic benefits of more efficient energy use. This has not encouraged the kind of universal response needed from all sectors of business. The responsibility for energy efficiency must be shared by all and not rest only on those that take environmental issues seriously. The EEBPP has recently been updated to cover the government's broader objectives of being customer focused, providing co-ordinated services, and making greater use of information technology (IT) and the internet.

When energy prices are relatively low, and in many manufacturing organisations energy costs represent only a small proportion of total production cost, emphasising the cost benefits alone will be unlikely to achieve the energy savings that are needed to contribute significantly to the UK's commitments.

It is understandable that energy efficiency campaigns have emphasized the direct economic benefits to be gained rather than the broader issues. Whilst this was acceptable in the past since even limited success contributed to some energy conservation, now much more must be done to stress the need for energy efficiency today. Initiatives in isolation are unlikely to achieve the reduction targets. A range of integrated initiatives focusing on industrial sectors and sub-sectors could be a more effective strategy. Strategies should be as diverse and varied as appropriate to achieve the overall objectives of reducing energy consumption and associated emissions of greenhouse gases. It may be necessary for all initiatives to be co-ordinated by one government agency.

Improving energy efficiency – doing the same work with less energy, is relatively simple and goes some way to reducing CO_2 emissions. The difficulty is to encourage business to implement measures that may be perceived to increase short-term cost. The alternative of imposing more stringent efficiency standards on goods and high energy taxes may not be politically acceptable to business.

2.6 Economic instruments

2.6.1 The Marshall Report

In 1998, the government set up an energy task force headed by Lord Marshall to look into ways that economic instruments could be used to encourage higher energy efficiency in the business sector and curb its energy linked greenhouse gas emissions. New tax incentive schemes were excluded from the brief of the task force. Recommendations for recycling any of the revenue from energy taxes raised to provide incentives to stimulate investment were also prohibited. The government stressed that all sectors of the economy must play their part to reduce greenhouse gas emissions.

A consultation paper (DETR, 1998b) was issued to which submissions were invited from interested parties on the subject of economic instruments, and if they could have a role to play in delivering emissions reductions by industry and improving the business use of energy. The paper stressed that measures must not handicap the competitiveness of British firms. The leading options under discussion were emissions trading and an industrial energy tax.

The consensus of respondents to the consultation paper was that economic instruments in the business sector would help to achieve the CO_2 reduction targets. Views differed widely on which instruments would work best, but most contributors to the Marshall Report (DETR, 1998b) agreed that a combination of 'a price signal, effective regulation, and grants and tax breaks would offer the most effective package'. Marshall concentrated on the two leading options – energy tax and tradable emission permits.

When published, the report considered the possibility of both tradable emissions permits and a tax on energy use. It was suggested that taxes would be more practical since all would be involved, whereas it was considered that at least in the short term it would be impractical to include small businesses in a permits trading scheme. Since SMEs account for some 60% of the total CO_2 emissions from business, it was vitally important that economic instruments applied to all businesses – regardless of size and energy usage. Marshall acknowledged that it is often smaller energy users that have the greatest cost effective potential for reductions.

The report called for a tax to be introduced at a low level and recommended that changes in the rates of tax should be made in a gradual and predictable way to maximize the incentive to invest in improved energy efficiency. To avoid damage to competitiveness, it was proposed that the revenues should be recycled *in full* to business – for example, through schemes promoting energy efficiency.

According to the Royal Commission on Environmental Pollution, (2000), the UK, along with other developed countries, will have to reduce CO_2 emissions eventually by up to 60% to stabilize the Earth's climate and that the targets set at Kyoto are just the beginning of a much longer process. Marshall was right therefore to assume that tougher reduction targets would inevitably follow those agreed at Kyoto in 1998, and proposed that the role of economic instruments should be part of a wider package of measures. Of the two types of instruments considered, Marshall said that emissions trading will be more important in the future and that Britain should set up a pilot scheme. The report also endorsed energy taxes, mainly to bring SMEs into the picture. It concluded that a tax was probably the only measure that would persuade SMEs to contribute to cutting energy related emissions to meet the Kyoto agreement.

When energy prices are relatively low, yet there is need to reduce its use for environmental reasons, an energy tax may be the only way to give business an incentive to cut its use. The leading option considered by Marshall was a 'downstream' tax on the final use of energy by industrial and commercial enterprises, with the rates being linked to the carbon content of the fuels used. However, it was proposed that the tax should be on energy use rather than 'carbon weighted' since the latter was perceived to be too complicated. For electricity, an Electricity Supply Industry (ESI) carbon emissions factor can be applied. The factor is based on the generation mix and the total output of the ESI. (ETSU, 1999b)

The conclusion of the report was that in the shorter term there was a role for some form of tax. It was doubted that it would ever be practical for most SMEs to participate in an international emissions trading scheme. It was suggested that part of the revenue could be used to promote schemes such as carbon trusts that promote low carbon technologies, and energy audit schemes for smaller companies. It was proposed that energy-intensive industries should be given special consideration that would reduce the impact of the tax but retain some incentive to save energy. One suggestion was a rebate system, but with the relief targeted at plant level rather than sectoral.

An energy tax on those industries with high energy usage such as steel making, metallurgical, paper, glass and chemical would reduce their ability to compete worldwide – a position that the government claimed that it wished to avoid. The Marshall report stressed that the design of the tax must be such that it does not harm the competitiveness of British industry, and in this respect it recommended that the revenues should be hypothecated within the business sector – and at least some of the revenue should be used directly to promote energy efficiency and reduce GHG emissions.

2.6.2 Climate Change Levy

In the longer term, a mix of policy instruments, will probably meet the government's goals most effectively, and with the lowest cost to business. In the short term, of the economic instruments considered by Marshall, it was decided that a form of energy tax would be the simplest to administer, the most direct, and likely to be the most effective. The government accepted this and proposed the Climate Change Levy (CCL) applied to gas, coal and electricity used by all businesses registered for VAT. When announced, there were immediate objections to the levy, particularly from energy intensive industries. Some said that the government should abandon the climate change levy altogether, on the grounds that it would be yet another unnecessary economic and regulatory burden on manufacturing industries.

There were several alternative suggestions from the critics of the levy that were discussed in Section 2.6.7. Some of these suggestions were naïve, such as the anecdotal proposition that the required reduction of carbon dioxide (CO_2) emissions could be achieved easily by replacing more coal-fired power stations with gas. This of course would have a serious impact on the coal industry, and it would not meet the UK's energy policy for *safe, secure and diverse* energy sources – particularly in the longer term.

According to the DETR (1998a), organizations waste around 20% of their energy. If this were so, even a levy of 15% would not impose an unreasonable burden on industry if it responded to the need to reduce energy intensity. It is generally accepted that most organisations could reduce their energy consumption by at least 10% at no cost by better 'housekeeping'. Therefore a 10% energy tax would be 'neutral' for those organizations that respond appropriately, and industry's competitiveness would not be affected.

2.6.3 Emissions trading

The Marshall report concentrated mainly on two options – a business energy tax and tradable emission permits. The conclusion was that in the short-term, a tax would be the better option, since it was doubted that it would ever be practical for most SMEs to participate in an international trading scheme.

Emissions trading has been shown to work. In 1995, the US government introduced an emissions trading scheme for sulphur dioxide, a mechanism for cutting local emissions without incurring a heavy cost on business. At the time, environmental groups regarded the scheme with caution but it reduced emissions significantly without imposing significant costs. Based on this experience, the 1997 Kyoto Protocol incorporated international emissions trading as one of the mechanisms for achieving global reductions in GHGs. Emissions trading is one of the 'flexible' mechanisms which the Kyoto Protocol permits countries to use for meeting their commitments.

In principle, a trading scheme would be quite simple. Companies would be allocated permits to emit a given quantity of CO_2 up to a specific limit. If a company emitted less than its limit, it could trade the surplus emissions with a company that is unable to reach its own targets cost effectively. The primary advantage of an effective emissions trading scheme would be that only a specified amount of GHGs would be emitted, with the potential of minimising the abatement costs of the participating companies. Proposals for such a scheme are being considered in Denmark, France, Australia and Canada.

There has been an increasing UK interest in emissions trading from both government and business. In 1999, the UK government and the CBI set up the Emissions Trading Group (ETG), with the remit to design a UK trading scheme that would be compatible with international schemes. The group aimed to deliver a scheme that was environmentally and economically credible, could be incorporated into the UK climate change levy agreements, and be open to as many participants as possible. The group published its outline proposals for the scheme in October 1999. The proposals set out a framework for a voluntary UK trading scheme that would be open to all companies.

It was proposed that participants in a trading scheme would fall into three main categories: absolute, unit and projects. *Absolute* participants would be companies that voluntarily accept an annual cap on overall emissions levels. Permits for absolute participants would be allocated on the basis of historical emissions levels. *Unit* participants would be companies that accept an output-related emissions target under a climate change levy agreement expressed in terms of energy or carbon per unit of output. Unlike the absolute participants, these companies would not receive permits directly but could buy them, or sell them, depending on their progress towards their targets. *Projects* participants would be companies that are not involved in either of the other categories. They would receive credits for specific projects that can be shown to cut greenhouse gas emissions.

A permit would convey the right to emit one tonne of carbon dioxide equivalent in a specified year. The scheme would be applicable mainly to energy-intensive companies, medium and large companies with significant energy costs, and the energy supply industry.

2.6.4 Proposals – *the debate*

It was intended that the climate change levy would provide an incentive to reduce business energy use. The prospect of an 'energy tax' was not welcomed by business but it should be conceded that a way to encourage energy efficiency was needed. Providing that revenues are recycled to industry sectors, competitiveness would not be affected; but the potential damage resulting from a badly designed scheme could be serious.

The levy, applied to the business use of energy in the way it was originally outlined in the chancellor's April 1999 budget speech, would have had a profound impact on the competitiveness of the UK's energy intensive manufacturing industries. Understandably, there was and still is fierce opposition to the levy from industry. But as businesses do not respond voluntarily to the call to reduce their energy use, then the government had no alternative to a levy and in future possibly other punitive economic measures to meet its commitments to reducing greenhouse gas emissions. But the revenue raised by a levy should be used to help the protection of the global climate – not to fund employment policy.

The government justified recycling the revenue from the levy by reducing employers' National Insurance (NI) contributions. It can be argued that this was to avoid the potential impact of the levy on employment by reducing labour costs in non-energy intensive service sectors such as retailing. It seems that the government never intended the levy to be fiscally neutral for business *sectors*, but revenue neutral for the exchequer. If the potential effect of the climate change levy is to be cost neutral for all business sectors, the revenue should be hypothecated within the discrete sectors from which it is collected to avoid an adverse effect on international competitiveness.

It is vital that an energy-based tax should be economically neutral for energy intensive manufacturing industries. The climate change levy announced by the Chancellor of the Exchequer in April 1999 may have been neutral for business as a whole, but it would not be neutral for most manufacturing industries if the revenue is used to NI contributions as suggested by the Chancellor. This is a misjudged response to the Marshall proposal for an energy tax that should be hypothecated so that it is cost neutral. Instead, the proposal to reduce NI contributions, (which in reality is a payroll tax), benefits firms with a large number of employees but not necessarily having a high energy use. Conversely, the proposed arrangements penalize those with few employees but with high energy usage. The latter face higher costs through the energy tax but without the compensatory reductions in NI contributions. Such a fiscal policy would appear to be designed to create jobs by reducing the cost of employment. This will not maintain the competitiveness of the UK's heavy industries, will encourage the service industries, and will not deliver on carbon emissions.

Firms that employ large numbers of people – such as retailers – but are relatively low energy users will gain without doing anything to improve energy efficiency. The proposal presented in the 1999 budget could fail to achieve any reduction in GHG emissions, and severely undermine the competitiveness of some of the most successful British industries. Reducing NI contributions will also be a disincentive for capital investment in new technologies that change the labour mix.

John Battle (1998) when energy minister said, "we must reduce [industrial] activities that consume energy, then improve the efficiency of what is left". This sounds more like the death knell for Britain's manufacturing industries rather than an equitable strategy to reduce global warming. So what *is* the government's agenda? It could be that by making the energy-intensive manufacturing sector uncompetitive internationally, the UK's energy related emissions compared to 1990 would be reduced as a result of energy intensive plant closures. Although this would help the government to meet its commitments, it would not reduce global emissions – in fact it is likely to increase them by transferring production processes to developing countries without restrictions. The government could meet its Kyoto target simply by driving manufacturing overseas, but the problem of greenhouse gas emissions would be merely moved abroad.

Even the Trade and Industry Select Committee (2000), criticized the government's planned levy, describing its design as a crude method of recycling revenues which would in effect transfer resources from the manufacturing sector to the service and public sectors. The select committee concluded that the government was right to make a bold commitment to meeting its Kyoto target, but it should *not* disadvantage British manufacturing.

The climate change levy has serious implications for energy intensive industries. There may be alternative ways to achieve the carbon dioxide reductions that are expected from the business sector to meet the government's commitments to the Kyoto Protocol and its unilateral target. Whichever strategy is chosen, UK industry should respond to the call for reducing its energy intensity, but it must be able to do so without jeopardising its international competitiveness.

The government's future plans should be phased so that technological and economic growth are not constrained, and the competitiveness of industry should not be impaired. These issues were the bases of the principal objections to the levy.

2.6.5 CCL – *the debate*

The focus of the issue behind the climate change levy – that of reducing the risk of climate change resulting from enhanced global warming – appears to have been lost. The UK has committed to make reductions in greenhouse gas emissions. This has to be achieved in some way, and the burden to deliver is on all energy users. Industrial users are highly 'visible' and may be a politically softer target than domestic and transport for any reduction strategies that the government may choose. High energy taxes on transport led to the disruptive actions of farmers and supporters in 2000 when oil refineries were blockaded in protest against high taxes on transport fuels. The government was forced to respond by reducing duty and tax levels.

Energy prices are low historically and low relative to many foreign competitors without indigenous energy sources. As energy costs are small as a proportion of production costs for many sectors of manufacturing, the financial incentive for energy saving is also small. The government had no alternative to some form of economic instrument. Market forces could not be relied upon for energy prices to rise significantly in the short term. Therefore energy costs had to be raised artificially – by taxes. It was evident from the initial responses to the proposals for the levy, from industry, trade associations and institutions, that this was very unpopular. The biggest single cause of the outcry against the original proposal for the levy, was its total lack of economic neutrality, which is a crucial condition if the strategy is to succeed on the two major counts – reducing carbon emissions and maintaining the competitiveness of UK business.

2.6.6 Objections

Most of the objections to the CCL were based on the potential effects on the competitiveness of British industries. The Institute of Energy (IoE), expressed concern that the imposition of arbitrary levies could have an adverse effect if other countries do not adopt similar levies on business energy use.

The Confederation of British Industry (CBI, 1999) opposed an energy tax as it would not only damage competitiveness, but also because it did not consider that an energy tax would be 'an effective or appropriate tool to reduce energy demand'. It argued that historically, energy demand has been price inelastic, therefore to influence behaviour significantly it would have to be set at a high level that would damage UK competitiveness. This would have an adverse impact on employment and investment. A high tax may penalize energy waste – but there has to be scope for the effect to be cost neutral for energy intensive industries that respond to the call for efficient use of energy.

Another concern of the CBI was that the government was considering an energy tax for business in isolation, while ruling out any new taxes on domestic energy use. There was no evidence to support this concern; but of course a new direct tax on domestic energy use would be a politically sensitive issue for the government.

The confederation's industrial policy group said that corporation tax relief for emission-reducing investments and reduction in National Insurance would be insufficient to return the original estimate of £1.75bn a year that would be raised through the CCL on business energy use. The CBI criticized the government's proposal to ring-fence only £50m, (it would have been less than 3% of the income from the proposed levy) for energy efficiency 'pump-priming' schemes on the grounds that there would be insufficient available to motivate smaller energy users to become more energy aware. The CBI did not believe that the 50% levy rebate offered later in the 1999 budget was sufficient to avoid major financial problems for several significant industries, some of which would be excluded from any rebate possibilities because they were not IPPC regulated industrial sites.

The Institute of Directors (IoD) in its research paper (1999) said that the case for environmental taxes and the case for their use should not be overstated. The IoD argued that eco-taxes must be designed to ensure that they are not counter-productive. The paper concluded bluntly that a tax that can stand up to critical examination of its purpose might benefit all – but a tax that is introduced on spurious grounds would be regretted.

The UK Steel Association, claimed that taxes on the steel industry, which had already halved its CO_2 emissions, would not deliver the targeted improvements and taxes would undermine the competitiveness of UK steel and reduce the industry's ability to invest in new processes that could bring further environmental improvements. *(The Engineer, 1999, Vol. 288, No. 7439, p. 8)* The association said that the only way a tax would achieve greater CO_2 savings from its own sector was through the loss of business to other countries and the closure of UK plant. This criticism of the levy proposals was typical of the metals sector in general.

In 1998, before the release of the Marshall report, the UK chemical industry agreed voluntarily to reduce its energy use by 20% of its 1990 level by 2005. A cut of 10% had already been achieved by the industry between 1990 and 1997. Chemical Industries Association (CIA) members estimated that an additional annual saving in carbon dioxide emissions of 550,000-900,000 tonnes could be realized above what would normally have been achieved from a "business as usual" approach – *without* the burden of an energy tax.

Based on the original levy proposal, the CIA estimated that its members would have paid £125 million in tax and only received £10 million in NI reduction. Even a 50% rebate of the levy would have meant a shortfall of £50m. Like the steel industry, the association threatened that the effect of this would be for production, and carbon dioxide emissions to be moved abroad.

In addition to the steel and chemicals industries, the issue of cost neutrality would have applied to other sectors; for example, the levy on the paper and pulp industry would have been £60m and only £2.5m saved in NI, and the cost to the cement industry would have been £40m and the NI benefit only £600,000. By contrast, the labour intensive service would have a significant net gain.

According to the Major Energy Users' Council (MEUC), the original rate of the energy tax would have added 15–20% to the bills of Britain's largest electricity users and seriously damage the competitiveness of UK manufacturing in general. (*The Engineer, 1999, Vol. 288, No. 7442, p. 2*) The MEUC referred to the government's proposal to refund part of the CCL to the companies that achieve emissions targets under Negotiated Energy Agreements (NEAs) as "legally dubious and unworkable". *(Energy World, 1999, No. 271, p. 5)*

The Energy Intensive Users' Group called for a *major* re-think of the design of the levy, to ensure that the government could meet its objectives *without* damaging business and said that "the potential damage from a badly designed tax is too significant to be ignored". *(Energy World, 1999, No. 271, p. 5)*

The Engineering Employers' Federation, (EEF) estimated that the CCL as originally proposed would cost heavy industry hundreds of millions of pounds despite the government's claim that the measure should be cash neutral. The big energy users said that the government's original plan to recycle the tax with a 0.5% cut in NI contributions would not have covered a *fraction* of their energy tax. The worst case envisaged was that of the steel industry that would have paid about £240m per annum and gained only £5m from reduced NI.

Cavenagh (1999:1) in a review of a report prepared for the EEF, said that it reinforced criticism from the Trade and Industry Select Committee (see below), that the CCL could cause job losses in a broad range of manufacturing industries – not just energy-intensive ones. The report warned that the levy would damage UK competitiveness and drive production to less environmentally friendly economies. The EEF pointed out also that any energy tax would harm those companies that had already made investments in energy efficiency improvements to reduce business costs. This argument is not justified since firms that had already improved their energy efficiency have the benefit of lower levy charges on lower energy bills.

The government claimed that the climate change levy would be "broadly neutral", but clearly the public sector – hospitals, schools, and government offices, and the service sector of business would benefit at industry's expense. This is not what the Marshall report proposed, which was that the revenue from a carbon tax should be 'ring-fenced' in order to ensure that the competitiveness of UK industry is not affected.

Following a critical response to the plan for the climate change levy from the influential House of Commons Trade and Industry Select Committee, in July 1999, the government was under pressure to amend its proposals for an energy tax. The committee described the levy as a 'blunt instrument', that would damage sectors of the economy that are already struggling to maintain their profitability. *(Energy World, No. 272, p. 5)*

2.6.7 Alternative proposals

Most objectors to the climate change levy offered alternative proposals for the government's consideration to address the perceived defects of the original proposals. The CBI (1999), for example, insisted that the original proposals for the levy were flawed and had to be improved to protect competitiveness and meet environmental goals more effectively. The confederation did not agree that tax measures could be 'cash-neutral'. As an alternative to tax, tradable permits and negotiated agreements were favoured and that these instruments should be used either separately or in conjunction – to enable business to meet reduction targets more effectively. The confederation emphasized that these two measures should be priority tools for the government, and that a tax should be considered only if these two measures proved to be ineffective.

The CBI continued its campaign and proposed that energy intensive companies be relieved of 95% of the costs of the Climate Change Levy. In exchange, it proposed that part of the NI rebate should be forfeited to ensure tax neutrality. The confederation submitted six key issues to the DTI for consideration:

1. There must be a levy reduction of more than 50% for the most energy-intensive users that sign negotiated agreements to reduce emissions. It suggested that the reduction should rise to 90% for some sectors if the levy was not to cause serious damage to some of the most important manufacturing sectors.
2. As many non-IPPC sites as possible should be included as eligible for negotiated agreements – possibly using Standard Industrial Classification (SIC) 1992 codes as a basis for eligibility.
3. The levy should make provision for emissions trading so that companies that undershoot their agreed targets could sell their surplus to those that exceed targets.

4. The Climate Change Levy is an environmental rather than fiscal measure. It should not be an instrument by which the Treasury can raise a specific amount of revenue. The proposed reduction in NI contributions should depend on how much money is raised by the levy after rebates and promoting energy efficiency schemes.
5. Nearly two-thirds of UK emissions come from small companies and non-intensive energy users. The £50m earmarked for promoting energy efficiency schemes should be increased to encourage small non-energy intensive companies to change their practices.
6. Renewable energy sources that do not contribute to carbon emissions should be exempt from the levy.

The CBI asked also for positive incentives for combined heat and power (CHP) systems. The Combined Heat and Power Association, (CHPA), stated that to meet the government's target of 10,000MW of installed CHP capacity by 2010, the revenue from levies should be fully recycled into low-carbon technologies as a matter of urgency. Such a policy would meet with the proposals included in the Marshall report.

Tax incentives for 'good quality' CHP were later announced by the chancellor who claimed that the climate change levy was structured in a way that would provide incentives for companies to improve energy efficiency and to boost the attractiveness of renewable energy schemes and on-site generation. However, on-site generation and CHP are not feasible options for most industrial sites where there is not a balanced need for heat and power.

The CBI also proposed that levies should be itemized on energy bills. This was not intended originally by the government. The confederation claimed that if the charge were not itemized, there would be little incentive for users to change their behaviour, particularly if energy prices remained low. It was not unreasonable, and the government did accede to this proposal also.

It was also proposed that the government could encourage conservation by agreeing targets for reductions, and taxing only the amount by which they are exceeded. This would not reduce competitiveness because it would not be penalising past behaviour.

The steel industry consistently argued for negotiated sector-wide agreements on CO_2 emissions. The UK Steel Association urged the chancellor to exempt entirely from the levy steel and other energy-intensive industries. The association proposed two measures in place of the levy:

- negotiated agreements whereby industries commit to reductions backed by legal penalties for non-compliance; and
- bonds to help finance investment in environmental improvements. The 'environment bonds' would be issued to the public with tax advantages and would be restricted to financing environmental improvements.

It was claimed that these measures would further environmental best practice without reducing UK competitiveness. *(The Engineer, 1999, Vol. 288, No.7439, p. 8)*

The Engineering Employers Federation (EEF) called for more than the £50 million to be available from the levy revenue for measures to encourage the uptake of energy-efficient practices and technologies. The federation proposed that a transitional period should be considered, prior to the introduction of any extra taxation, to enable industry to invest in energy efficiency technology.

The EEF also recommended that the proposals for the levy should be redesigned to reflect the carbon content of the fuels. This was an impractical suggestion. A 'carbon tax' was not proposed because it would be too complex to apply and administer. The proposed levies *do* reflect the carbon emissions from different fuels. In the case of electricity, the 'generating mix' determines the carbon emissions factor.

The chemical industry is the UK's largest manufacturing export earner, but in September 1999, treasury ministers refused to discuss the issues of the levy with a CIA delegation. According to the CIA, the government could meet its climate change targets without adversely affecting industrial competitiveness. The CIA proposed that groups of companies or industrial sectors should set energy efficiency targets and commit to continuous improvement, in return for exemption from the energy tax, 100% rebates, or a capping mechanism. The CIA wanted to limit the schemes to total group or sector energy consumption above a specified threshold – a system used in Holland, where the threshold is 0.5 petajoules per annum.

The CIA proposed that a levy should stimulate companies to join demanding energy efficiency schemes, irrespective of the company size or sector in which it operates. The association claimed that the advantages of its proposals were:

- it would be open to all industry;
- it would change behaviour and promote an energy efficiency culture;
- companies entering into challenging agreements and meeting targets would enjoy true cost neutrality via rebates, exemptions or capping mechanisms, (as in Germany);
- business users that do not form agreements would pay the full levy;
- UK would meet its Kyoto targets, but with industrial competitiveness preserved, and manufacturing industry continuing to underpin the UK economy.

The Institute of Energy (IoE) endorsed energy taxes in principle, but proposed that other economic instruments be explored. The IoE believes that the public in general still need to be convinced of the need for energy saving and for emissions reductions. Unless this can be addressed successfully, it may become necessary for higher efficiency standards for energy using equipment to be introduced. This would move energy efficiency improvement further up the supply chain.

The House of Commons Trade and Industry Select Committee proposed that the government should introduce a lower rate of corporation tax for companies that reduce their emissions beyond an agreed baseline. This was considered be too complicated, as was the alternative put forward, namely that the tax should be applied to the quantum by which an agreed target is exceeded. The committee concluded that a better way may be to introduce higher capital allowances for investments in energy efficiency projects and tax relief for approved R&D expenditure on energy efficient technologies.

2.6.8 Summary of the Marshall Report debate

Many of the complaints about the so-called energy tax may have exaggerated its likely effects. A study by the Ecotec (1999), based on Office of National Statistics figures, showed that the net cost of the tax for the most energy intensive industries would be equivalent to a maximum of 3% of net sales after national insurance reductions were taken into account. However, for many companies, including some foundries, even 3% increase in cost would cancel the net profit at a time when many firms are in desperate difficulties due to the strength of sterling against the euro.

The Royal Institution of International Affairs debated and voted in favour of the government's intention to introduce a climate change levy but there was a consensus that the proposal needed improvement. The institution's two main criticisms of the original levy proposals were:

- the method of recycling the revenue would effectively take money from the large energy users which employ few people and give it to modest energy users which employ many people;

- the £50 million earmarked for boosting investment would be inadequate to cause any significant effect – many argued that much more of the revenue should be used in this way.

Some of the other alternatives that emanated from the debate included:

- reduced rate of corporate taxes for companies which actually reduce their emissions by a measured amount from an agreed baseline;
- encourage energy conservation by agreeing targets for reductions; and
- taxing only the amount by which targets are exceeded.

These measures would not reduce competitiveness and would not penalize past poor behaviour, but they would be complicated to administer. Negotiated energy agreements (these are discussed later), are unwieldy and not guaranteed to deliver the required reductions in energy use. The documentation, maintenance of records and third party auditing will add yet more regulatory burdens to participating firms.

Energy cost is often a relatively low proportion of total business expenditure and partly because of the insistence by business on short payback times for investments in energy efficient technologies. When energy prices are low, payback can sometimes be several years – well beyond that usually expected to justify investment.

Low energy prices in recent years have taken energy efficiency off the agenda of many companies, and only legislation or higher prices will put it back. However, while the climate change levy may alter the behaviour of major energy users, it is less clear how smaller energy users and those whose energy represents a low proportion of total cost, will have an incentive to change.

Regardless of whether there is a direct tax on business energy use or any of the alternatives such as emissions trading or negotiated energy agreements (NEA), the commitment must be met. Emissions trading alone is not appropriate since it could not include smaller enterprises. Although it is likely to be a useful tool for larger enterprises in the medium to long term. For the short-term, an alternative to both NEAs and trading, may be to enforce the government's commitments by setting mandatory sectoral reductions based on allocations for emissions for all business use. Dispensation should be considered only where mandatory reductions would impose non-relievable financial impacts.

In the longer term, a mix of policy instruments will probably be needed to meet the government's objectives most effectively with the lowest cost to business. Whichever way is chosen, there will be a cost that can only be avoided by the intended response – that of reducing energy waste.

Government ministers indicated that they had heard the critics and would review the initial design of the tax. The decision to extend the consultation period by two months to October 2000 led to some speculation that the proposed CCL might be scrapped. However, the government considered that the CCL was the best means by which the UK could meet its emissions targets, and its implementation had to be as quickly as possible.

2.6.9 Revised levy

Objectors' views were heard, including many from those that did not respond to the Marshall Consultation Paper. It was perhaps unfortunate that some sectors of UK manufacturing, including aluminium casting, were apathetic towards energy and environmental issues and failed to contribute to the debate before the government formulated its strategy. Whilst most of the objections to the proposal for a climate change levy were sound, many of the arguments ignored the fact that all have an obligation to contribute to reducing energy related emissions.

The original proposal for the levy would have raised £1.75 billion of revenue. The proposed levy rates were for:

- coal - 0.21p/kWh;
- gas - 0.21p/kWh;
- LPG - 0.10p/kWh;
- electricity - 0.60p/kWh.

Based on energy prices at the time, the tax at this level on electricity equated to 10-20% of cost, and gas would have been 20-30%.

In response to the protests from energy intensive industries, the government reduced the initial levy rates. In the 1999 Autumn Statement, the chancellor announced that the proposed climate change levy would be reduced by 29% and there would be 80% rebates available for sectors that had NEAs. The current levies are:

- coal - 0.15p/kWh;
- gas - 0.15p/kWh;
- LPG - 0.07p/kWh;
- electricity - 0.43p/kWh.

The revised proposals went some way to reduce the potential burden of the levy on energy intensive industries. The revisions were a response to the clamour from those industries, but it is unfortunate that the government did not implement fully the recommendations of the Marshall Report in the first place. It could have avoided some of the acrimony that ensued from the original proposals.

Energy costs represent a relatively small proportion of the total production costs of many industries. This may be so, but the levy on energy will not be only on a company's direct energy use, it will be reflected also in the prices of all inputs that have 'embodied' energy – metals, chemicals and other process consumables. The overall impact could damage international competitiveness.

Despite the reductions to the proposed climate change levy, there were still complaints. Some UK manufacturers threatened that they could shift production elsewhere. Obviously, there would be no environmental gain if industries such as steel were forced abroad by the levy. Therefore levy rebates and other tax incentives for heavy energy users had to be considered.

The DETR Select Committee criticized the revisions in that they failed the test of good taxation, and that the system of exemptions, negotiated agreements and rebates would produce *"an extremely complex and cumbersome market instrument"* which would result in relatively modest emissions reduction. *(The Engineer, 2000, Vol. 289, No. 7496, p. 5)*
The government expects the promised energy savings to boost the levy's expected reduction in greenhouse gas emissions from 1.5 to 4 million tonnes of carbon a year. But the committee claimed that the proposed scheme places undue reliance on untested, unproven energy efficiency agreements between government and industry. The select committee's report suggested that the government should adopt a more imaginative approach to recycling levy revenues, including tax incentives for energy efficiency investments. (This was not included in Marshall's remit).

The CCL in its original form was based on the assumption that *all* energy use is bad. This is not so, it is wasteful and inefficient use of energy that is bad. The intention of an energy tax is to change behaviour. But if this is to work, there should be a carrot as well as a stick.

If the revenue is not used to fund incentives for firms to reduce their energy related emissions, the levy will be seen as yet another financial burden imposed by government on ailing manufacturers.

Deputy Prime Minister Prescott announced that a lower rate of levy would be offered to those energy intensive users that 'sign up to energy efficiency gains'. The government's intention was for the reduced rate to apply to those firms that accepted targets for improving energy efficiency in line with government-set criteria. Negotiated energy agreements were made between the government and energy intensive sectors of industry. The agreements were based on specific energy consumption (SEC) not the *total* use of energy, which would stifle growth.

2.6.10 Negotiated energy agreements

In 2000, memoranda of understanding for negotiated energy agreements (NEA) were signed between the government and bodies representing the steel, aluminium, cement, ceramics, chemicals, glass, non-ferrous metals, metal casting, and food and drink industries. Energy reduction targets were agreed in return for an 80% discount off the climate change levy. Most parties welcomed the concessions, but even the modified levy is unlikely to be financially neutral for the heaviest energy-consuming industries.

Each sector included in NEAs must demonstrate that it has undertaken the energy efficiency improvements committed to in return for the levy discount. If a sector fails to meet its obligations, individual companies in the sector will be audited and those that fail will have to repay their discount. The returns will be audited, and the conclusions published

Sectoral targets have been set for 2010, with two-yearly 'milestones'. The timetable is intended to allow industry to plan for energy savings that will require long-term change and investment. The agreements are intended to allow for sector-wide targets, rather than just site-based targets and encourage more resourceful thinking and optimisation of available resources.

The government decided that only industrial processes covered by the Integrated Pollution Prevention and Control (IPPC), regime would be eligible to enter into negotiations for levy discounts. This created yet another argument. There are many industrial processes that are regulated under IPPC for discharges not related to climate change. It is perverse to grant levy concessions to these when there are others outside IPPC which have higher energy intensities but would not qualify for discounts.

The proposals for levy discounts for firms that sign NEAs could present difficult administrative problems. Agreed energy reduction targets are based on relative energy – 'specific energy consumption' (SEC) or absolute energy. SEC will require systems for recording and verification of outputs of saleable product from every site as well as energy inputs. It must allow also for the effects on SEC of changes in a firms product mix and output. (The NEA targets for the foundry sector is summarized in Annex D).

Trade associations continue to campaign on behalf of firms that have not been allowed to negotiate energy agreements and have to pay the tax in full, but the associations recommended that the best response for those without NEAs should be to invest in energy efficiency. This is precisely the response that is expected by the government.

The base dates set for negotiated agreements vary from sector to sector. This takes account of the substantial reductions in carbon emissions that have been made by some sectors under voluntary agreements made since 1990. This has satisfied demands for credits to be given for the savings already made since 1990. This was not an unreasonable request; however, such claims have to be substantiated by verification of independent auditors. The scheme must minimize the possibility of fraudulent claims. It will be a challenging task for government agencies.

2.7 Sectoral targets

All sectors of business are different, as are individual companies in the sectors. Therefore there is a strong probability that any policies designed to encourage energy efficiency that are tax or levy based will create anomalies that could seem unfair to some sectors and types of organisation. The government attempted to avoid such consequences but it was probably inevitable that for some there will be unfavourable economic impacts that can be construed as unfair.

The objective of the climate change levy in its original form was to achieve an average reduction in business use of energy to at least match the emissions reductions targets set by government. Such a simplistic approach did not address the adverse effects on the international competitiveness of high energy sectors. The amendment of both the level of the levy and the introduction of discounts as part of negotiated agreements are intended to address this problem without affecting the outcome of the policy.

The proposal for negotiated Climate Change Levy Agreements (CCLAs) between sectors of industry and the DETR was based on ETSU's assessments for energy reduction targets. The targets were inevitably challenged by the energy intensive sectors, which countered with their assessments of reductions that were *acceptable* rather than *achievable*. Compromises were made.

ETSU's original specific energy reduction target for the cast metals sector was 21%. As would be expected in what was to become a bargaining situation, the cast metals sector claimed that "a sensible energy saving would be less than 5%". The ETSU target was later amended to 19.4% and audits made for the sector indicated that 7.8% reduction was feasible. After extensive lobbying by the foundry sector's negotiating body – Target 2010, the NEA target for the cast metals sector was eventually set at 11% energy reduction for which there would be an 80% discount from the levy. In effect, the discount reduces the levy rate to 0.030 p/kWh for gas and 0.086 p/kWh for electricity. On average, net cost increases will be around 4% for gas and 2% for electricity. In the case of the latter, the increase will be more than offset by the new electricity trading arrangements (NETA). Also, the cost of the levy will be partially offset by a 0.3% reduction in employers' National Insurance contributions. However, there will be some costs associated with installation of sub-metering systems, energy management systems and auditing fees.

Having established that the targets were achievable and accepted by the business sector, the instruments to reduce energy use were then amended to deal with the impacts on the most energy intensive sectors. The strategy allows a phased introduction of emissions reduction measures to encourage progressive responses from business.

2.8 Research questions

Under the negotiated energy agreement whereby foundries could qualify for 80% discount of levies, the sector's original target was set by ETSU at 21% and later amended to 19.4%. The sector's response was that it would be difficult to justify committing to more than 5%

reduction in SEC. Subsequently, random site audits indicated that 7.8% was achievable. The DTI finally set the target 11%. Naturally, most firms claim that this will be difficult to achieve at least without significant investment. This research investigates the existing situation in aluminium foundries by gathering data by case studies.

The case studies provided practical information about operating procedures and identified areas of energy waste that could be reduced by introducing no-cost or low-cast measures for improving energy efficiency. Using the data, the effects of measures are quantified to find what contributions they would make towards meeting the sector target.

The specific research questions are:

- What is the existing situation?
- What measures could be undertaken?
- What would be the impacts of the measures?
- What contributions could be made by a) the aluminium casting sub-sector, b) the foundry sector and c) industry in general?

2.9 Summary

In November 1999, after extensive lobbying by high energy using sectors, the government offered the chance of levy discounts of 80% of the levy to certain industries, and exemptions in some cases. However, there was some concern that the levy rebates would have been construed as 'state aid' and disallowed by the European Commission. The UK government was confident that the rebates and exemptions would be cleared by the commission, as they were. If rebates had been treated as state aid, they would have been repayable. The costs of the levy might have been unacceptably high for some energy intensive sectors to continue to operate in Britain. This situation could also arise if only *some* developed countries apply carbon taxes, or the taxes vary substantially among the participating countries, then the sources of energy intensive goods could move from more efficient and more environmentally advanced countries to less efficient countries. This effect has to be avoided if the objectives of the Kyoto Protocol are to be fulfilled.

The government has a mandate to meet its international obligations and pledges to the electorate. The commitment to the United Nations Environmental Programme (UNEP) and its unilateral one to reduce CO_2 emissions by 20% are explicit. Therefore the government is obliged to take all steps necessary to meet these commitments – even though there may be objections from some sectors of business and some sections of the public. It may be assumed that before making the commitments for reducing energy related carbon emissions, the government's advisors would have investigated potential impacts on business in general and on energy intensive industries in particular. Strategies to meet commitments should have been carefully formulated to take account of all potential negative impacts.

From the Marshall report, it seemed that the most equitable and acceptable instruments would be a carbon-based tax and emissions trading. These would have the least negative impacts on competitiveness and also deliver the emissions reductions without risking transfer of energy intensive industries to unregulated regions.

The government's plan for a tax on energy drew widespread criticism up to the publication of the plans for the climate change levy in the 1999 Budget, there had clearly been sufficient consultation with the kinds of firms that would be adversely affected. There was some consultation after the budget announcement, but the concept of the levy was set.

There is a paradoxical contrast in the government's energy price strategies – namely, the cost increase from the climate change levy and OFGEM's regulation of the electricity distributors. The purpose of a tax on energy use is to encourage businesses to change the way they use energy. But OFGEM ordered electricity distribution price reductions from 2000 to 2005. There was a one-off reduction averaging 25 to 30% from April 2000, and then a cut of 3% below the rate of inflation for the following four years. Distribution costs represent around 15-20% of a typical industrial electricity user's bill. The proposed cuts result in a reduction in the total price of electricity of around 2.5-4% for commercial customers. The cuts were welcomed by industry, but the energy efficiency incentives expected from the climate change levy, have been diminished.

The abolition of the electricity pool and its replacement with market-based NETA could also lower industry's power bills by at least 10% according to the Major Energy Users' Council and the energy industry regulator – OFGEM. Lower electricity prices will reduce the initial impact of the climate change levy. This will relieve totally the pressure on major energy users to improve efficiency of electricity use.

Since other energy saving initiatives failed to produce the desired results, some form of tax on the use of energy by business can be justified. It is too late to remove the climate change levy from the statute book, but to ensure fiscal neutrality for British industry, it is *not* too late to consider alternatives for more equitable recycling of the levy within the business sectors from which it will be collected. As the government has decided to use taxes to goad firms into action, then there should also be incentives in the form of grants and tax breaks to encourage firms along the way.

There is sufficient information available to indicate that all sectors of business can make major reductions in energy use. Many sectors, including foundries, disagreed with ETSU's assessments of the large energy savings that could be made. Those that disagreed probably could not provide proof of their claims if they were called upon to do so. All of the objectors have signed up to negotiated energy agreements, suggesting that the reductions were possible and the initial reaction to the original targets was based on the perceived economic impact of the levy on production costs.

Undoubtedly there is scope for CO_2 savings by improving energy efficiency in all sectors of the UK economy. In the short term, raising awareness should be a priority task for government agencies, to stimulate universal interest in energy and reducing its waste.

All sectors of society must be included in strategies to reduce greenhouse gas emissions; it is essential that the burden does not fall unfairly on any one section of society. Certainly, policies must be designed to be effective without jeopardising the competitiveness of UK industries. The government's goals will only be achieved by creating a balance between environmental, social and economic issues. Major behavioural change by business will be vital for energy efficiency improvement. The change may not be achieved by the present arrangements.

The objective to reduce the energy intensity of the UK's manufacturing sector will be encouraged by the CCL and the incentives of discounts. The government had little scope to satisfy objectors to the original levy proposals, but it is doubtful if the emissions reductions will be met without some amendments to the existing levy scheme.

Chapter 3: Research methodology

3.1 Introduction

The practical problem identified as a result of the analysis presented in Chapter 2, is to find ways that would allow UK industry to remain internationally competitive while complying with government policy to reduce CO_2 emissions through a levy that threatens to raise manufacturing costs.

The theoretical problem, that rising levels of greenhouse gases in the earth's atmosphere could enhance the greenhouse effect leading to climate change, has been addressed by the international community's acceptance to reduce greenhouse gas emissions. The UK is committed to contribute to the abatement process and the government has made a strategic decision to meet its commitment by introducing a levy on energy used by business as the first step to reduce CO_2 emissions. It is possible that this reduction could raise manufacturing costs, especially for energy intensive sectors, to the extent that they would become uncompetitive against international competition. To avoid this consequence, energy intensive firms need to reduce their specific energy consumption (SEC).

The research that has been undertaken investigates the problem that companies in the aluminium casting sector have in reducing current CO_2 emissions by improving their SEC by eliminating energy waste. The aluminium casting sector was chosen for this study because it is under competitive pressure and is energy intensive. It is representative of other sectors of industry faced with the impacts of the climate change levy. The industry also offered access for primary research activities. The overall aim of the investigation was to address the research problem by gathering sufficient representative data of energy use within the aluminium casting sector to enable a model to be built that would provide the means to assess the impact of energy-saving measures. To achieve this overall aim, the investigation addressed the research questions that were identified in Chapter 2:

1. What are the current technologies employed in UK aluminium foundries?
2. What are the current operating practices in relation to the technologies identified in question 1?
3. What is the existing SEC of the industry?
4. What operating or technological measures are available to eliminate or reduce energy waste?
5. What effect would these measures have on the SEC of the industry?
6. What contribution would the implementation of these measures make to the reduction targets set by the DTI?

The first four of these questions were answered by questionnaire and interview surveys, and case studies. Questions 5 and 6 were answered by building a spreadsheet model of energy consumption in the case study foundries and testing the various scenarios against it. The relationship of the research questions to the research methodology and investigative techniques is summarized in Figure 3.1 and will be discussed in the remaining section of this chapter.

3.2 Research strategic choices

The primary research strategy explained in this section was implemented using the protocols that will be discussed in the following section. Three types of investigation (Figure 3.1) were carried out to provide multiple sources of evidence from which answers to the first four research questions could be deduced. A sector-wide questionnaire and a series of interviews were undertaken to find the industry's perceptions of, and attitudes to energy efficiency in general, and measures to reduce carbon emissions.

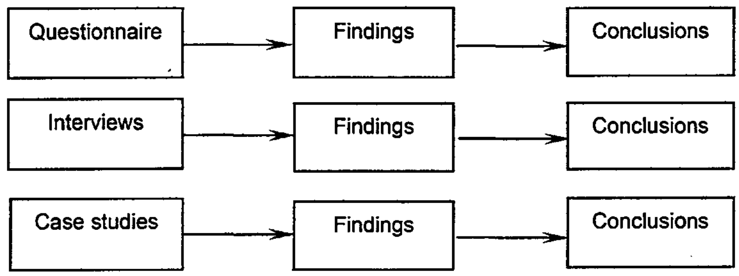


Figure 3.1. ***Multiple sources of evidence.***

The investigation was undertaken in four phases. The aim of *Phase 1* was to gather data that would provide a broad background picture of the current position in the sector. A particular interest was to identify the companies' perceptions of and attitudes to improving energy efficiency and the extent to which measures to improve SEC performance and reduce carbon emissions had already been undertaken. A questionnaire-based survey of companies in the sector was used to gather a range of background data and a series of interviews provided more in-depth information on the perceptions and attitudes of executives within the companies.

The aims of the questionnaire survey were to:

- determine the level of interest in and relevance of the key factors for the research outlined above; and
- collect information on the current energy efficiency improvement activities of the sector.

Phase 2 of the primary research consisted of three detailed case studies of technologies employed, process flows and operational practices in three aluminium foundries. In addition, kilowatt-hour and gas flowmeters were used to gather data on the energy used for melting aluminium and holding it in the molten state prior to casting.

Phase 3 involved formulating a hypothesis that, together with the knowledge gained from Phases 1 and 2, could be used for constructing a spreadsheet model that could be used test the effects of various modifications to the climate change levy on the companies used for the case studies.

The *final phase* of the investigation consisted of undertaking a series of experiments to find what levy structure would meet the government's reduction target for the sector and be achievable by the case study companies without increasing production costs.

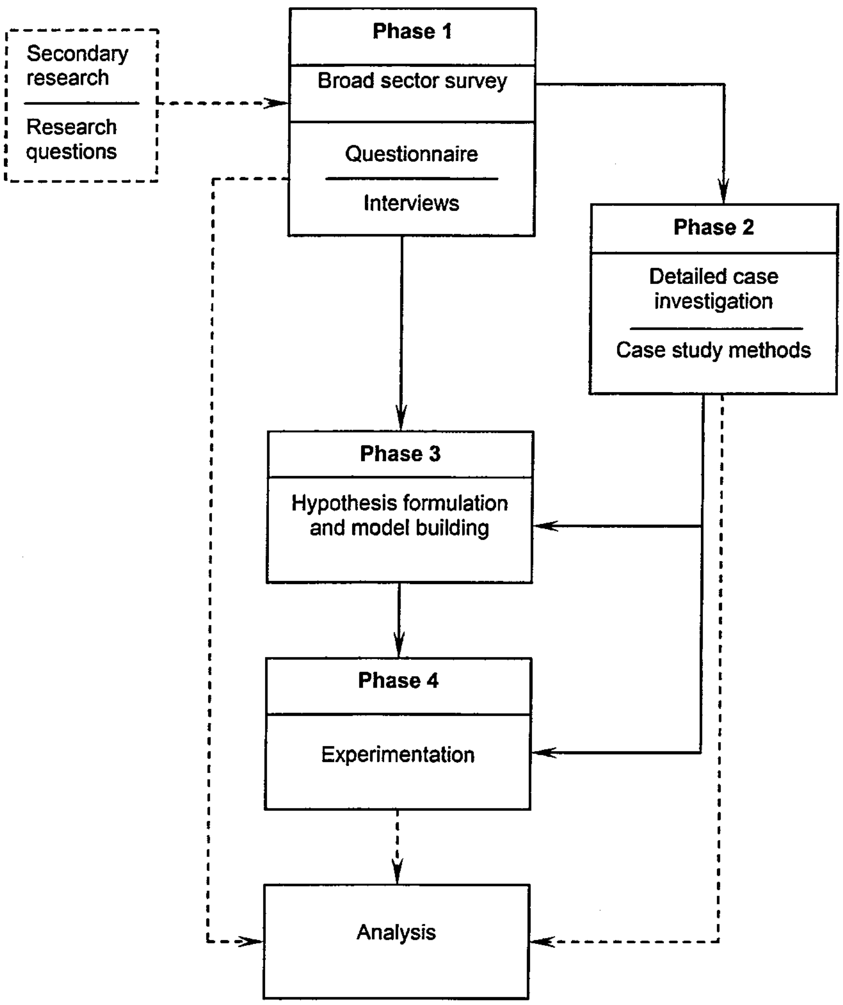


Figure 3.2. ***Elements in the investigation strategy.***

The relationship of the various elements in the investigation strategy is shown in Figure 3.2.

The questionnaire (Appendix I) was sent to a random sample of 54 aluminium foundries. The questionnaire included 39 questions in five sections. Section A was used to categorize the respondents' companies in terms of casting process, metals cast and fuel used for melting and holding. Section B elicited information about business size by number employed, location, markets and affiliations to trade bodies. A further three sections covered environmental management, energy efficiency and general environmental issues relating to climate change and government policy.

Between 1998 and 2001, formal interviews were conducted with a dozen aluminium foundry managers who agreed to discuss their companies' energy and environmental policies. Subjects were selected to represent firms of various sizes, casting processes and furnace systems. Appointments were made by telephone when the structure of the interview was outlined so that interviewees could prepare commercial information. Several people working for organisations closely involved with the sector were also interviewed. The group included researchers, trade bodies and consultants. During the site work for the case studies, there were opportunities to informally interview people 'on the foundry floor' to whom access would not normally have been possible.

The main topics covered by formal interviews were:

- government policy on energy use;
- actions to encourage industry to reduce material and energy waste;
- economic instruments to encourage better energy management;
- energy efficiency standards and regulation;
- energy efficiency awareness; and
- energy management and corporate policy.

The idea that there is scope for reducing the specific energy consumption (SEC) of energy intensive industries without adversely affecting cost competitiveness was developed in Chapter 2. The case study method (Figure 3.2) was used to support the theory by providing quantitative data for a model in which experiments could be made to develop and prove the hypothesis offered in Chapter 5.

One of the aims of the research was to identify the attitudes of senior managers within the industry sector to environmental issues and the need to reduce CO_2 emissions. It was recognized that a conventional postal survey was unlikely to be a sufficiently interactive data gathering technique to enable a rounded picture of attitudes to be obtained. For this reason it was decided to undertake a series of interviews with foundry managers. The questionnaires and interviews were the two components of Phase 1. They provided the background for the design of the case studies that were undertaken during Phase 2.

Using a multiple case study methodology, Phase 2 consisted of three detailed investigations. Each case was selected so that it would either a) produce similar results (*literal replication*) or b) produce contrary results but for predictable reasons (*theoretical replication*). Yin (1994) reasons that multiple case studies:

- produce more robust evidence than a single case study;
- use the underlying logic of replication not sampling.

In terms of this research specifically, the case study method was chosen because it provided a framework that:

- enabled the problem of emissions reduction to be studied holistically;
- provided the means to gather data under practical operating conditions.

The overall objectives were to assess:

- the existing SEC of the industry;
- the measures could be taken to reduce SEC;
- the effect the measures would have on SEC;
- the contribution the measures would make to meet the government's emissions reduction targets.

As Figure 3.2 suggests, the data gathered during the case studies were used as the basis for a series of experiments undertaken using the model built during Phase 3 of the primary research. The aim of the model and experimentation was to find a form of simplified levy scheme that could be used to meet the sector's energy reduction target without increasing overall energy costs.

Energy waste reduction by better housekeeping can often be easy to implement with minimal cost. But better housekeeping should only be seen as a first step towards improving energy efficiency. Better process control and production planning, together with raising mould yield are likely to be some of the most effective tools for meeting the government's targets set for the sector.

To evaluate the potential of these actions, the specific aims of the case studies were to:

- measure the energy inputs and metal melted;
- measure the efficiency of the furnaces;
- observe current practices, and
- calculate the specific energy consumption (SEC) of the casting processes.

The principal objectives of the studies were to identify opportunities for improving energy efficiency to:

- mitigate the economic impact of the climate change levy;
- reduce energy use to offset future energy price rises;
- evaluate cost effective energy improvements;
- extrapolate findings for the aluminium casting sector; and
- compare SECs with published industry averages.

Three companies gave access to their plants to allow operational data to be gathered under normal working conditions. Operational data covering the energy used and casting production was collected on each site over a period covering at least a normal working week.

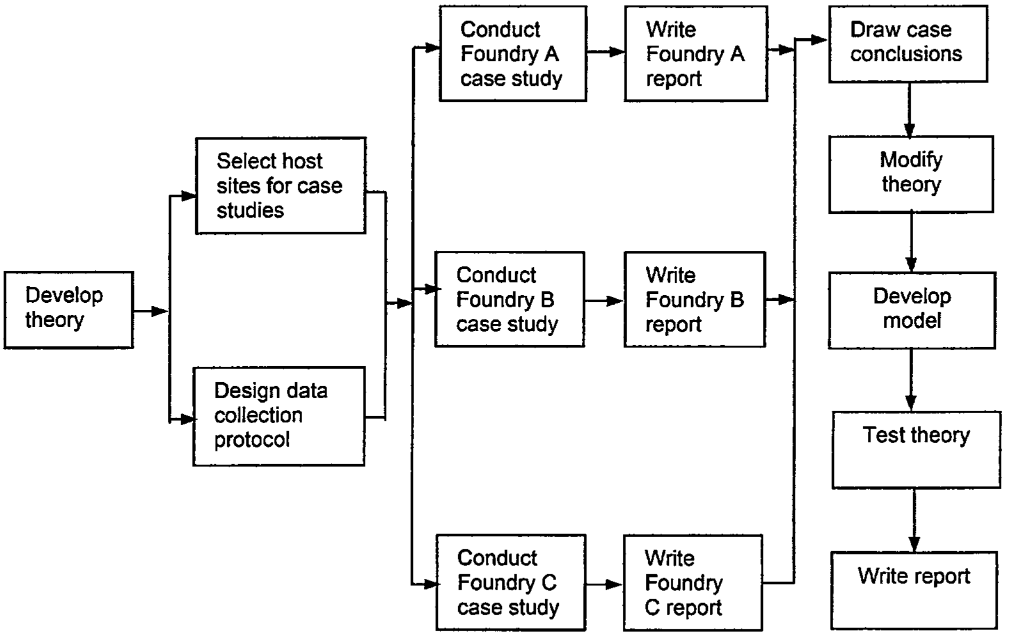


Figure 3.3. ***Yin's case study method applied to the investigation.***
Based on Yin (1994)

The host sites selected:

- use the three main casting processes for aluminium alloys – gravity diecasting, high pressure diecasting, and sand casting; (These three processes are used to produce approximately 95% of aluminium castings in the UK)

- use all of the most commonly used types of melting and holding furnaces – gas-fired 'tower' furnaces and crucible furnaces;
- use both gas and electricity for melting and holding;
- were sited in the West Midlands, (two) and rural Wales (one).

Table 3.1. ***Host sites for case studies.***

Site	Casting process	Melting fuel	Holding fuel	Annual output (tonnes)
Foundry A	Gravity die	Gas	Electricity	
	Low pressure die	Gas	Electricity	1083
Foundry B	Sand	Gas	Electricity	970
Foundry C	High pressure die	Gas	Elec. & gas	3600
	Gravity die	Electricity	Electricity	218

The three foundries used gas-fired furnaces for pre-melting metal that was then transferred to holding furnaces from which it was dispensed into the moulds. The layouts of the foundries are illustrated in Figures 3.4 - 3.7.

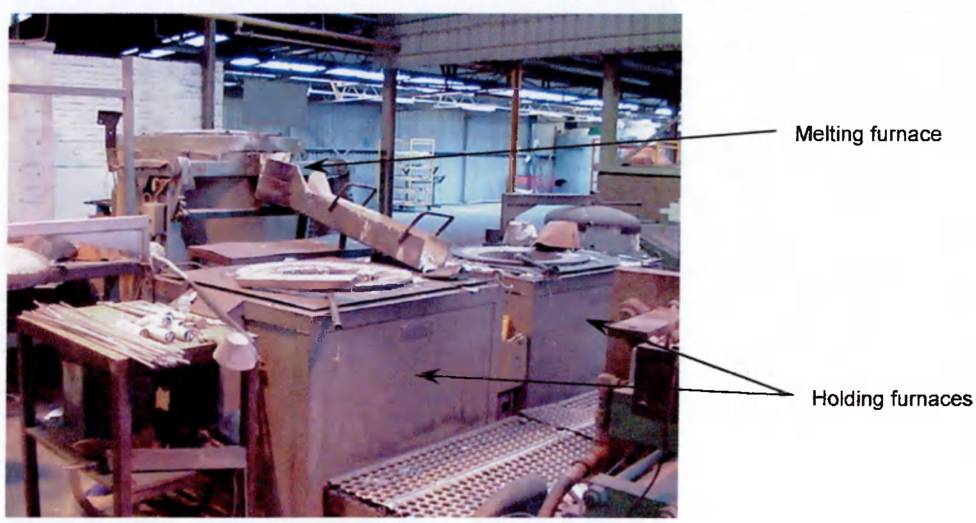


Figure 3.4. ***Arrangement of melting & holding furnaces in Foundry A's diecasting cells.***

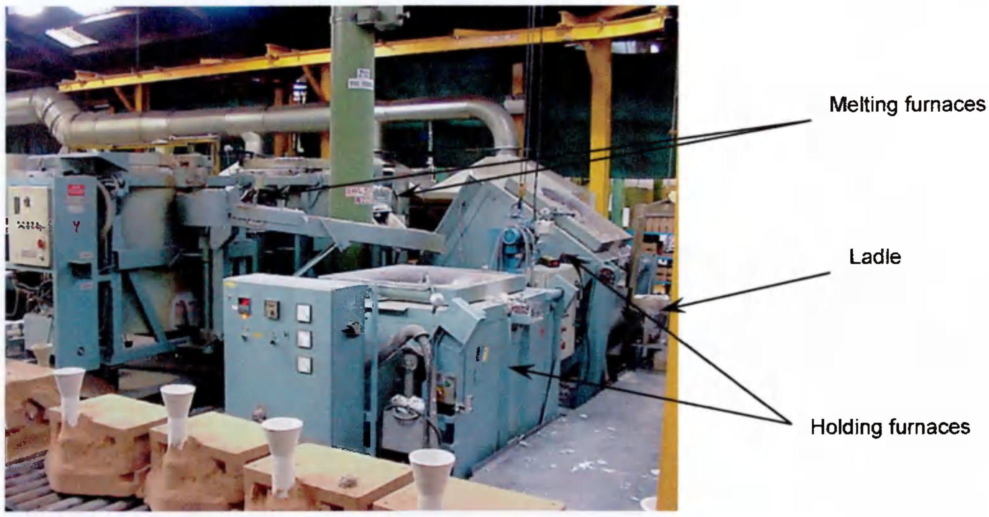


Figure 3.5. ***Arrangement of melting & holding furnaces in Foundry B's 'production foundry'.***

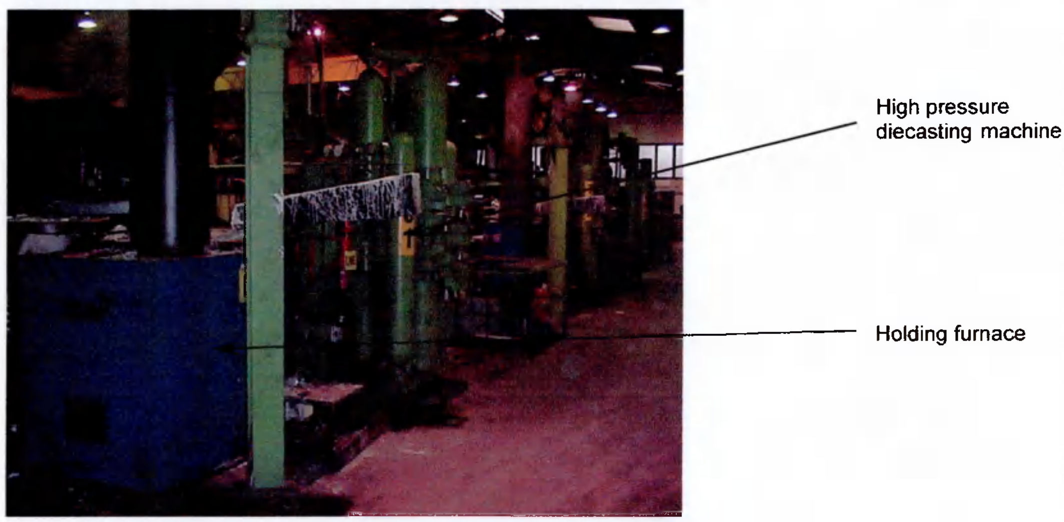


Figure 3.6. ***Arrangement of 700 t high pressure diecasting machines & holding furnaces at Foundry C.***

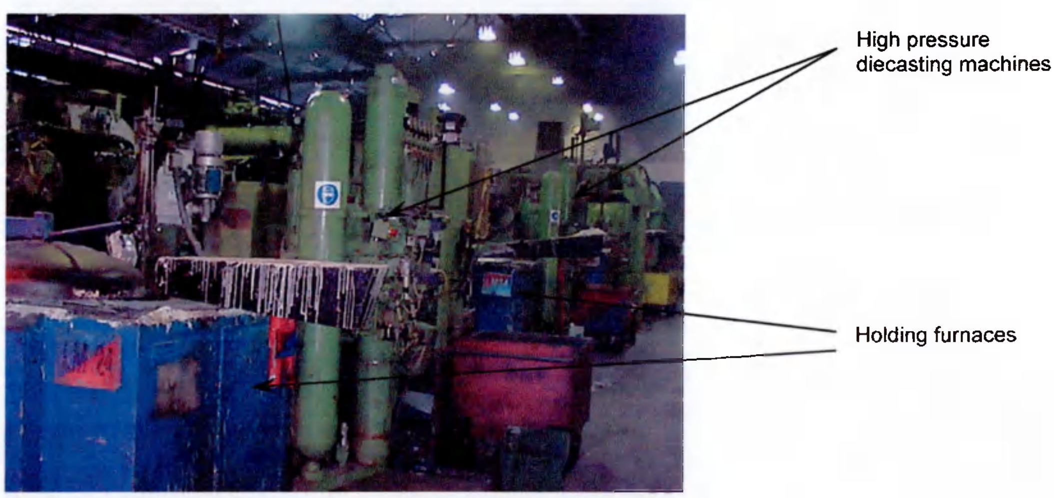


Figure 3.7. ***Arrangement of 400 t pressure diecasting machines & holding furnaces at Foundry C.***

3.3 Possible measures

The case studies revealed many possibilities for no-cost and low-cost measures for energy efficiency improvement. The measures having a payback of two years or less were used for the experiments in the spreadsheet model.

3.4 Experiment by modelling

Purpose

A spreadsheet model was designed to test the hypothesis that an alternative strategy based upon incremental levy rates would produce the necessary reductions in business energy use without:

- impairing the international competitiveness of energy intensive industries;
- negotiated energy agreements;
- levy discounts;
- reducing employers' NI contributions;
- imposing undue administrative costs on business;
- third party audits.

Experiments were made using the model to test various levy rates and alternative modes of application that would be economically neutral for the host sites used for the case studies.

Construction

1. The total site usage of electricity and gas, are used for each company.
2. Electricity costs for each site were lowered by 10% to reflect the reported changes since 2000.

3. Gas prices were *increased* by 60% from 2000 since when new contracts have been signed.
4. Electricity is converted to primary energy using a delivered to primary conversion factor for purchased electricity of 2.6 for the period 2000-2010. (ETSU, 1999)
5. 2000 outputs and energy mix were used.
6. Levies are applied incrementally in 4 phases from 2001 to 2010.
7. Costs of energy improvement measures, including energy management are included.
8. Annual gross energy costs fixed for the timeframe of the model.

Aims

To examine the effects of various levies on energy use and costs:

- Investigate the effect of the schemes on energy reduction in each host company to neutralize cost impacts of various incremental levy rates.
- Select the postulation that meets the sector's 11% SEC reduction target without incurring increases in gross energy costs.

The formulae shown below were built into the model under the headings on the blank spreadsheet Figure 3.8.

Base year minus one (y-1):

Electricity used (delivered)	E_{y-1}	(kWh)
Gas used	G_{y-1}	(kWh)
Total energy used	$E_{y-1}+G_{y-1}$	(kWh)

Base year (y_0):

Electricity price (P_e)	$= 0.9P_{e(y-1)}$	(£ kWh^{-1})

Gas price (P_g) $= 1.6P_{g(y-1)}$ (£ kWh^{-1})

Electricity cost (E_{y0}) $= P_eE_{y-1}/(E_{y-1}+G_{y-1})$ (£)

Gas cost (G_{y0}) $= P_gG_{y-1}/(E_{y-1}+G_{y-1})$ (£)

Total energy cost (C) $= E_{y0}+G_{y0}$ (£)

For each year of the model:

Electricity used (delivered) $(E_d) = (C-M)E_{y-1}/(E_{y-1}+G_{y-1})/(P_e+R_e)$ (kWh $annum^{-1}$)

Gas used $(E_g) = (C-M)G_{y-1}/(E_{y-1}+G_{y-1})/(P_g+R_g)$ (kWh $annum^{-1}$)

Primary energy used $= 2.6E_d+E_g$ (kWh_p $annum^{-1}$)

Where: (1) C is constant.

(2) M is the annual cost of reduction measures (£).

(3) R_e is the levy rate on electricity (£ kWh^{-1}).

(4) R_g is the levy rate on gas (£ kWh^{-1}).

Several levy regimes were applied to the model for each year in several experiments. Levies applied were:

(1) Current rates for Foundry A, and current rates less 80% discount for Foundry B & Foundry C; and

(2) Various incremental rates.

Costs of reduction measures were based on estimates for each site. (Appendix III) Estimates were agreed with the persons responsible for energy matters on each site. The variables were applied to find for each postulation:

(1) Annual reduction in electricity use compared to base year;

(2) Annual reduction in gas use compared to base year;

(3) Annual reduction in primary energy use compared to base year;

(4) Final reduction in electricity use compared to base year;

(5) Final reduction in gas use compared to base year;

(6) Final reduction in primary energy use compared to base year;

(7) Levy costs proportional to total energy costs;

(8) Costs of reduction measures proportional to total energy costs.

	Year 0	Phase 1	Phase 2	Phase 3			Phase 4			
		2002	2003	2004	2005	2006	2007	2008	2009	2010
Levy on electricity (£ kWh^{-1})										
Levy on gas (£ kWh^{-1})										
Electricity price (£ kWh^{-1})										
Gas price (£ kWh^{-1})										
Total gross energy cost (£ $annum^{-1}$)										
Cost of measures (£ $annum^{-1}$)*										
Total energy cost (£ $annum^{-1}$)										
Electricity use (kWh $annum^{-1}$)										
Electricity cost (£ $annum^{-1}$)										
Electricity levy (£ $annum^{-1}$)										
Total electricity cost (£ $annum^{-1}$)										
Gas cost (£ $annum^{-1}$)										
Gas levy (£ $annum^{-1}$)										
Total gas cost (£ $annum^{-1}$)										
Electricity use (kWh_p $annum^{-1}$)										
Saving to neutralize										
Gas use (kWh $annum^{-1}$)										
Saving to neutralize										
Total primary energy use (kWh_p)										
Electricity use reduction (kWh_p $annum^{-1}$)										
Gas use reduction (kWh $annum^{-1}$)										
Total levy (£ $annum^{-1}$)										
Total net energy cost (£ $annum^{-1}$)										
Levy as proportion of cost										

Figure 3.8. ***Headings for spreadsheet model.***

The outcome of the experiments is discussed in Chapter 4 and the broader implications are discussed in Chapter 5.

3.5 Research procedures

3.5.1 Questionnaire and interviews

In 2000, a questionnaire (Appendix I) was sent to 54 of the 260 aluminium foundries operating in the UK. Half of the questionnaires were sent to foundries with which the author was familiar and had names of contacts with information needed to answer the questions satisfactorily. The second group was selected randomly from the listings in the *Foundry Yearbook*.

The questionnaire was developed from previous research undertaken in 1997 (Ramsell, 1997) and was not piloted. Questions covered organisational aspects, (number of employees, output, location), metal melting and casting process, energy use, energy management and site specific and general environmental issues. It was designed to produce a profile of each responding company and a basis for a general profile of the sector.

Responses were received from 33 firms (61% of the sample) being 15% of the sector total. The size of organisations when rated by number of employees ranged from less than 20 to more than 250. Annual outputs ranged from 25 to 2500 tonnes – the total from all respondents being 30,000 tonnes, which is approximately 15% of the annual output from UK foundries.

Interviews

Two groups of interviewees were selected – the main one being with persons within foundry companies. The second group was persons working for organisations closely involved, for example suppliers, researchers, trade bodies and consultants.

In general, the format of interviews followed that of the questionnaire and included the questions used to establish the organisational aspects, (number of employees, output, location), metal melting and casting process, energy use, energy management and site specific and general environmental issues of the interviewees' companies. Interviews produced more comprehensive responses to the questions related to the more general attitudes towards energy and environmental issues.

Interviews were conducted at interviewees' premises and lasted approximately two to three hours followed by a site tour. This enabled interviewees to provide most of their operating information on the spot and permit clarification of details when necessary.

3.5.2 Case study methodologies

Where possible, combustion conditions were measured on gas-fired furnaces by analysing the composition of the waste gases using a proprietary instrument. The instrument measured O_2, CO, CO_2 and the excess air coefficient λ. ($\lambda = CO_{2max} / CO_2$, where CO_{2max} is the fuel-specific constant (11.7 for natural gas) and CO_2 is the concentration in %)

Calibrated scales were used on each site so that the poured weight and trimmed weight (running system removed) of castings could be measured to establish mould yields. Production records for each shift were made available so that the total output from each casting cell or machine could be recorded against the energy used by the respective furnaces. From this, furnace efficiencies and SECs were calculated. The amount of dross generated and its metallic content were estimated with assistance from the operators.

Data from the case studies were used to support proposals for cost effective energy efficiency improvement measures in each host foundry. The findings provided the bases on which sector-wide assessments, projections and extrapolations could be made. The findings were compared with published data for the industry.

Melting and holding furnace performance tests were made under normal operating conditions to measure the SEC of the process. Energy inputs were metered. Only six of the sixteen furnaces used for the studies incorporated energy meters. Gas and electricity meters were installed on the remainder for the duration of the studies. Electricity meters recorded kilowatt-hours (kWh). Gas meters were graduated in cubic meters per hour. ($m^3 h^{-1}$)

Turbine-type gas meters were used. These instruments are calibrated for a pressure of 1 bar. Dynamic gas pressures were taken, and correction factors* applied to the meter readings.

Methodology – Foundry A

A digital flowmeter was installed in the gas supply to the melting furnace. The flowmeter recorded the gas volume in m^3, and displayed the flow-rate in $m^3 h^{-1}$. An integrating kWh-meter was connected to each electric holding furnace.

Casting production and energy used were recorded on five operating days with a weekend between two of them to give a representative working week. Due to operational problems it was not possible to monitor the cell for an unbroken run. The days were taken at random so that the data gathered covered the production of several types of castings made by different operators. Weekly averages for energy used and weight of metal cast were

* Boyle's law is applied: $V=p_1V_1/p$ – where V_1 is the metered volume and p is the absolute pressure.

calculated. The total energy used was also recorded for the whole period of nine working days.

For the purposes of the study, data from Cell 3 (Tables 4.2 & 4.3) were taken to be typical for Foundry A's six cells. This was for the foundry as a whole. The operating procedures were reviewed in the light of the findings. Opportunities for energy saving were identified and quantified.

A detailed report was prepared for presentation to the management of Foundry A. The contents of the report were discussed and the responses of the management team were recorded to be included in the review of the interviews undertaken for this research.

Methodology – Foundry B

A survey for the case study was carried out over a full week of 168 hours. According to the host company, the casting mix and output were typical for the section of the foundry. The quantity and weight of castings were recorded for each day. An integrating flowmeter was installed in the gas supply to each melting furnace and kilowatt-hour meters were connected to each holding furnace. The energy used by each furnace was recorded for the corresponding production period. (Tables 4.5a – 4.6b). The data from the survey was extrapolated for the whole casting operation in Foundry B.

A report was produced and presented to the directors and engineers. Feedback from the meeting was incorporated in the interview analysis in Chapter 4.

Methodology – Foundry C

A survey was conducted over a full week of 168 hours including a weekend break. The machines and furnaces monitored were chosen by the production director and were considered to be representative for the casting mix and output of the foundry. The quantity, poured weight and trimmed weight of castings from each of the monitored furnaces were recorded for each day. The gas and electricity used by each furnace was also recorded for the corresponding production period. (Tables 4.8a – 4.9c) The SEC was calculated and extrapolated for the total output of the Foundry C.

The results of the study were discussed with the production director who had board responsibility for site energy management. Relevant points from the discussion were incorporated into the interview research analysis.

The case study research undertaken on the host sites is reviewed and opportunities submitted for no-cost or low-cost energy saving measures that could be undertaken by the host foundries without incurring major costs.

The on-site work for the case studies provided opportunities for ad hoc informal interviews with line managers and operatives. This was an invaluable source of additional practical information to complement that gathered by the formal interviews.

3.5.3 Analysis of research

Findings from the questionnaire and interviews were analysed and are discussed in Chapter 4. Related work done by others was reviewed and compared with this. The data gathered during the case studies were recorded and analysed, and then compared to the published work of ETSU – the latter being the only authoritative research available on this specific topic. Analyses of the results of the research led to the assessment of measures that the aluminium casting industry could take to reduce energy wastage. The possible savings are estimated and the potential to alleviate the economic impacts of energy saving measures and a levy on energy use is examined.

3.6. Summary

The observations from the questionnaire and interviews are reviewed and analysed in Chapter 4 and discussed subsequently in Chapter 5. The data from the case studies are collated in Chapter 4 and used to develop the model described in Section 3.4. The results of experiments with the model are used to advance the concepts for an alternative levy scheme that could overcome the weaknesses of the existing scheme, meet the government's targets for the sector and not reduce the competitiveness of the industry. The outcomes of the experiments are used to test the hypothesis submitted in the final chapter and the scope for an alternative strategy to meet the carbon emission reduction targets by realisable reductions in specific energy consumption is investigated.

Chapter 4: Research findings

4.1 Introduction – Industry background

The UK foundry industry census (DTI, 1998) showed that there were 577 operating sites. By 2000/2001, the number had reduced to 480, of which 23% were casting aluminium. (Cast Metals Federation, 2002) According to the census, in 1997 – 199,300 tonnes of aluminium castings were produced in UK foundries. Although the use of aluminium castings in vehicles has increased, the annual output for all uses from UK foundries has remained around 200,000 tonnes. Fifteen per cent of UK of output is exported – 13% to EU countries.

The production of aluminium castings is highly dependent on the output of the automotive sector and the sector's use of the metal. The average content of aluminium castings in cars and light trucks is now in the order of 120 kilogrammes per vehicle.

Other major markets for aluminium castings are also expanding with global economic growth. Two thirds of UK produced aluminium castings are for the automotive market. The increasing demand for domestic appliances, other consumer goods, and office machines, and the greater use in electrical and civil engineering, will increase further the output of aluminium castings significantly over the next decade.

As an energy intensive industry, the non-ferrous metals sector has a relatively low profile, unlike iron and steel, and chemicals for example. The aluminium casting sector's environmental externality may seem even benign compared to others. However, as will be seen from the research, this is not so. Furthermore, the environmental impacts from aluminium casting will increase with growth in demand. Against a background of growth, benefits from environmental and energy improvements will be more significant.

Around 60% of the energy used in the production of raw (as-cast) aluminium castings is for melting, and then holding in the molten state prior to casting. This research and that of ETSU (1994) indicate that in many aluminium foundries, there is an average metal loss in the order of 5% incurred in the molten state. With this metal loss, there is the associated energy waste and CO_2 emissions to air.

Using existing technologies and modest investments can make some improvements in the sector's performance. In the longer term, more efficient melting technology and different operating practices will be needed to minimize waste of both energy and materials. There are opportunities for the aluminium foundry industry to reduce its specific energy consumption, but there is no single model melting and holding system that could be replicated throughout the sector.

4.2 Results of surveys and case studies

4.2.1 Melting aluminium for casting

Casting processes

There are two basic reasons for melting aluminium, either to change its composition - alloying, or to change its form by processing in its liquid state - casting. The main aluminium casting routes are:

- *diecasting* - casting in dies or 'permanent' moulds;
- *sand casting* - casting in expendable sand moulds;

- *investment casting* - casting in expendable ceramic moulds.

There are variants of the first two of these processes:

- *diecasting* – gravity filling;
  – high pressure filling;
  – low pressure filling.
- *sand casting* – gravity filling;
  – low pressure.

Sand casting is the oldest and probably the simplest process for producing complex cast metal forms. Various methods are used to make sand moulds; selection depends upon several factors including casting complexity, accuracy, size, and production requirements.

Gravity diecasting utilizes a metal mould into which molten metal is poured either from a manual or mechanical ladle, or directly from a pressurized dispensing furnace. The moulds are used repeatedly for medium to high production volumes of moderately complex shapes.

Low-pressure diecasting employs a ferrous alloy mould into which the liquid metal is counter-gravity fed from a pressurized holding furnace under the machine. This process is widely used for producing car wheels and other high quality complex shapes.

High-pressure diecasting uses steel moulds mounted in machines in which the metal is injected under high pressure by a piston in the machine. The machines require high capital investment that is justified for the manufacture of high volume, dimensionally accurate, near-net-shape castings.

Investment casting is a technique that is mainly used for producing small, complex shapes with good surface finish and to near net shape. Wax patterns are progressively coated with ceramic slurry to form a shell. The wax is melted out to leave a ceramic mould into which liquid metal is poured.

Gravity diecastings account for approximately half of the aluminium castings produced in UK foundries. One third are high pressure diecastings, 8% sand castings and 5% low pressure diecastings. The balance is from other processes such as 'lost foam' and investment casting.

Furnaces

A variety of furnace types are used for melting aluminium prior to casting. Some have externally heated crucibles to contain the melt – known generically as 'crucible furnaces'. Others employ refractory lined chambers heated from above by burners or electric elements, these are known as 'reverberatory furnaces'. Electric induction furnaces are not widely used in aluminium foundries; those used are mainly 'bulk' melting for on-site production of specification alloys using internal scrap and bought-in scrap as feedstock.

Furnace selection depends upon many operational considerations such as output, number and type of alloys, casting process, availability of fuels and their cost, space available, environmental constraints, capital cost, maintenance requirements, and ease of operation. However, furnace efficiency in terms of both energy and metal yield (net output after oxidation losses) is often of secondary importance in the selection process to most of the criteria listed.

Metal loss

Improving melt quality is of paramount importance for better casting quality and reducing scrap and the associated waste of material and energy. Figure 4.1 shows typical material flows during casting production. The specific material wastes from the system are trimmings from as-cast components, (sprues, runners and risers), and metal oxides in the form of dross and slag.

Dross skimmed from the surface of molten aluminium prior to pouring varies in its composition; the amount of metal entrapped in dross may range upwards from 30% by weight. The metallic content of the dross depends upon several factors including the alloy composition of the charge, the melting procedure followed, and the care with which the dross is removed. The dross can often represent a substantial processing loss; therefore efforts are justified to recover as much aluminium as possible.

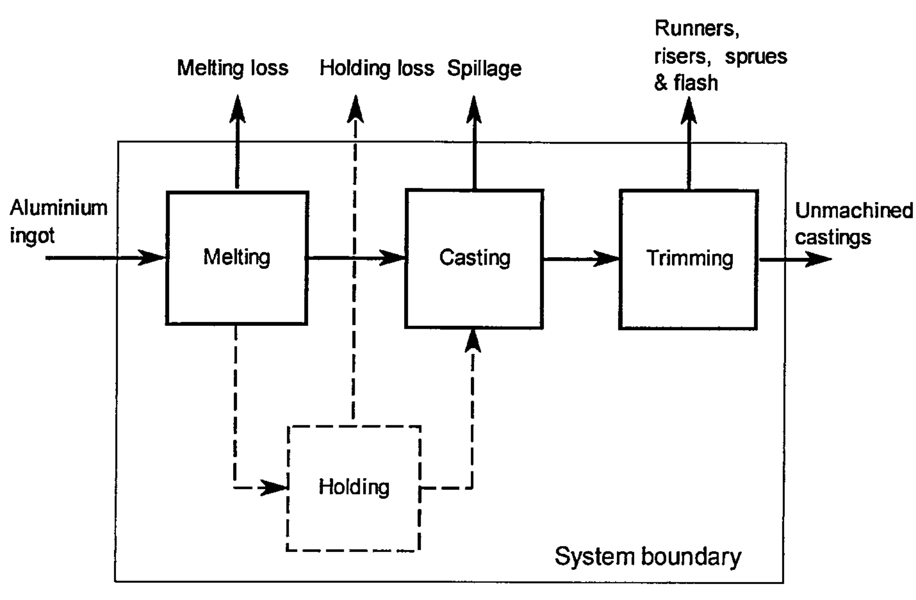


Figure 4.1. ***Flow diagram for the production of unmachined aluminium castings.***

Some of the metallic losses are recoverable within the system. (Figure 4.2) For example, trimmings, which are the waste portion of castings, unless they are contaminated or out of specification, often may be recycled directly through the melting furnaces on site.

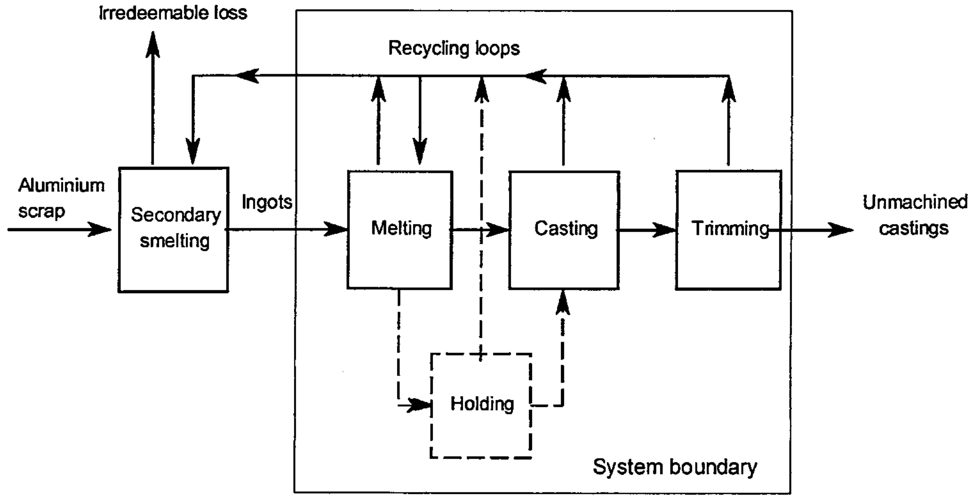


Figure 4.2. ***Flow diagram of the melting and casting process with recycling loops.***

Dross is usually sent to specialist recyclers for processing. The final material losses are reduced then to the irredeemable fraction only. Aluminium lost by oxidation during the melting process is significant in the environmental context because of the high amount of energy invested in the metal during its conversion from bauxite, and the emissions associated with its production and reprocessing. Also, the irredeemable waste, (which may be contaminated by chemicals used for treatment), must be sent to landfill adding to the environmental impact of wastes.

Casting quality

The production of scrap castings is probably the largest single source of energy waste in foundries – scrap also wastes resources in general and lowers profit. Quality improvement has been a pre-occupation of UK industry for the last couple of decades. Product quality is directly related to energy efficiency since the one of the aims of quality management is to reduce scrap.

Advanced techniques have been devised to avoid the generation of defects developed during mould filling, but these techniques are not fully effective unless the melt is free from gaseous and solid contaminants when it is transferred. Measures must be taken to correct the condition of the melt by controlling its temperature and preparing its metallurgical composition.

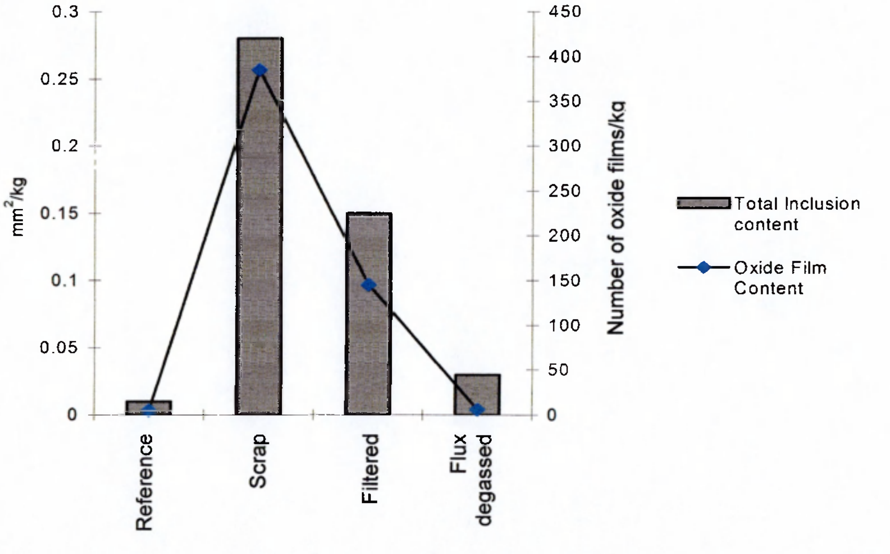
Time and temperature above the liquidus influence the loss of alloying elements that are characterized by low vapour pressure and high reactivity. The potential for depletion applies to elements such as sodium, calcium, strontium and magnesium. Deficiencies of these elements influence the physical properties of castings that then may be scrapped – creating further wastes of material and energy. Therefore it is important to: a) control the temperature of the melt to the lowest level compatible with the alloy, its chemical treatment and casting process, and b) to minimize the time that the metal is held in the liquid state.

The adsorption of hydrogen into aluminium in the liquid state results in a dissolved hydrogen content which may rise up to the equilibrium value for the specific alloy composition and its temperature. The sources of hydrogen in molten aluminium are – moisture from the ambient air, products of combustion in flame heated furnaces, furnace and ladle linings, and the charge material itself. Dissolved hydrogen in the melt causes casting porosity, which for many products is unacceptable since the mechanical properties are impaired. As it is not often practicable to rework aluminium castings, the result of porosity is waste in the form of scrapped castings.

Aluminium alloys oxidize readily. When aluminium it is melted, a continuous oxide skin forms on the surface. When the skin is disturbed or removed, a further oxide skin forms. In this way a build up of oxide will result which can later be trapped in the melt.

Aluminium oxide films have almost the same specific weight as the melt itself; therefore they are suspended in the melt and are transferred to the finished casting unless action is taken to prevent it. It is important to reduce the formation of oxides for quality control and reduce metal loss.

Devices for determining hydrogen levels in aluminium alloys are well established, but until recently a means of monitoring levels of oxides and other inclusions was not been readily available. Recent innovations in metal cleanliness measurement techniques can now be utilized to control this aspect of melt quality.



Left axis: Cross section of inclusions per sample. Right axis: Number of oxide films per sample.

Figure 4.3. ***Effect of process variables on metal cleanliness.***
Source: *N-Tec Ltd (UK)*

Figure 4.3 shows the results of tests using a new measuring technique that demonstrates the effectiveness of rotary flux feeding when used with a suitable flux for the removal of inclusions. The bars on the chart show the total content of inclusions in one kilogram samples of metal on the surface of polished test piece samples measured as mm kg^{-1}. The number of oxide films in the sample also can be counted in samples as indicated on the right axis of the chart. Both are a measure of 'metal cleanliness'.

When used with appropriate chemicals, the rotary degassing and flux feeding system is effective for modification, silicon refinement and trace element removal. Much of the development work on fluxes currently taking place is aimed at reducing the environmental effect of fluxing, both by flux design and efficiency of the injection processes. The development of rotary flux feeding has enhanced molten aluminium alloy treatment by combining the best features of rotary degassing and flux injection in a single device. The process also reduces waste by lowering the metallic content of the dross generated.

Summarising, every part of the casting process uses energy, but some of the links to energy efficiency are not always obvious. This brief résumé highlights the most important aspects of the process. In simple terms, improving energy efficiency means doing the same work with less energy, which can often be achieved by reducing all forms of waste by eliminating their causes.

4.2.2 Questionnaire and interview survey

Questionnaire

The format of the questionnaire (Appendix I) was described briefly in Chapter 3. The questionnaire was sent to a random sample of 54 aluminium foundries. Responses were received from 33 firms – 61% of the sample and representing 30% of the sector total.

Section A of the questionnaire solicited information about the respondents' foundry operations. Fifty per cent of responses were from foundries that make gravity diecastings only. Another third were principally gravity diecasters but having secondary casting processes. Thirty-three per cent specialized solely in high-pressure diecasting. Ten per cent are sand casting only, but 48% of all did some sand casting as a secondary manufacturing route. The mix conforms closely to that of the 1997 census (DTI, 1998). At the time of the questionnaire survey, all respondents were casting aluminium alloys, a third also cast zinc or copper alloys also but aluminium was the predominant metal for 83% of these.

Casting outputs ranged from less than 250 tonnes per annum per company, to more than 2000 tonnes – the highest being almost 4000 tonnes. The estimated output of saleable castings produced by the respondents was 30 180 tonnes per annum. This is about 15% of the UK output and seems to be a representative sample for the sector. From the responses, it is estimated that 60 000tonnes of aluminium would be melted to produce the declared output, indicating an average mould yield of 50%.

Table 4.1. ***Summary of questionnaire responses relating to business size, capacity & fuels used.***

Persons employed	<50	50-100	101-250	>250	
Sites	14	4	3	9	
Casting process	Gravity	HPDC*	LPDC**	Sand	Mixed
Sites	24	11	3	16	10
Principal casting process	Gravity	HPDC	LPDC	Sand	
Sites	11	5	1	3	
Output (tonnes/annum)	<500	500-1000	1001-1500	1501-2000	>2000
Sites	7	5	7	2	2
Metal melted (tonnes/annum)	<1000	1001-1500	1501-2000	2001-3000	>3000
Sites	8	3	4	5	3
Principal melting fuel	Gas	Electricity	Oil	LPG	
Sites	11	11	1	0	
Principal holding fuel	Gas	Electricity	Oil	LPG	
Sites	2	14	1	0	

* High pressure diecasting
** Low pressure die casting

Sixty per cent of the foundries use both natural gas and electricity for melting; half of them favour gas as the main fuel. The breakdown of energy use by type and monthly output is depicted in Figure 4.4. Electricity was favoured for holding metal in the molten state by eighty per cent of respondents.

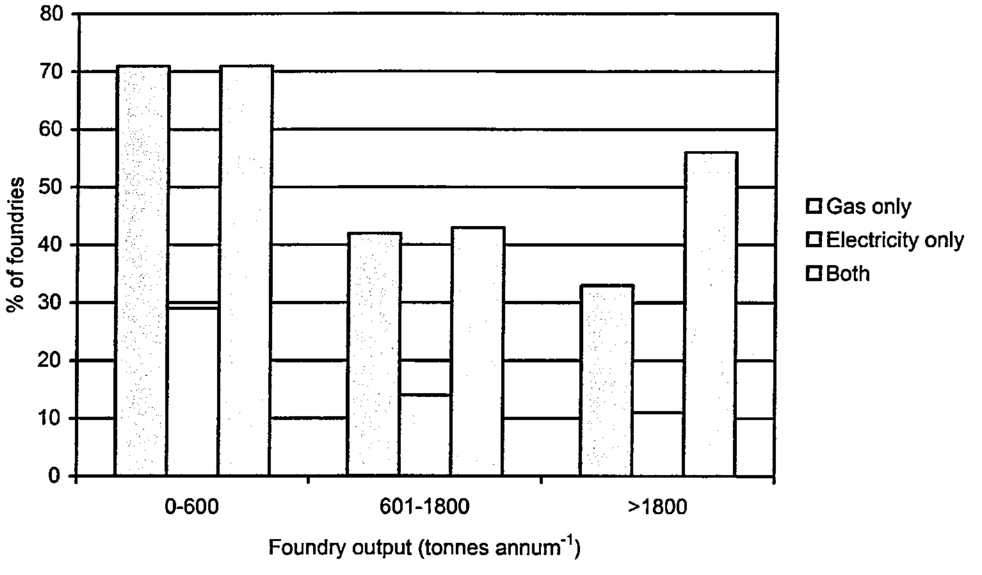


Figure 4.4. ***Fuels used for melting in aluminium foundries.***

Section B of the questionnaire was designed to categorize the commercial aspects of respondents. Eighty-two per cent of the foundries had an average of 75 employees and are classified by the DTI as SMEs. Eighteen per cent employ more than 250 persons – classified as large enterprises.

Approximately half of the foundries were located in industrial or mixed urban areas. The others were in either urban residential or semi-rural locations. There is no evidence that foundries located in residential or semi-rural areas use electric furnaces to reduce the impacts on the local environment of noise and emissions from gas and oil-fired furnaces.

The automotive industry was the principal market for all of the larger participating foundries (those producing 1000 tonnes per annum and above). The mechanical engineering sector was the second most important market for aluminium castings, followed by electrical engineering. White goods make up only a small proportion of the respondents' business. The sector's main export market is Continental Europe, 24% of the foundries supply to customers in North America.

Eighty per cent of the respondents are members of the EEF or the CBI. Three quarters of the responding persons are members of the Institute of British Foundrymen (recently re-named Institute of Cast Metals Engineers) or of the British Metal Casting Association (now incorporated into the Cast Metals Federation).

This study and those of others have found obvious distinctions that present opportunities upon which to focus. For example, company size has some bearing on response to external pressure. Also, company size usually gives some indication of the type of management structure and authority of personnel likely to be responsible for energy management and other environmental matters.

Environmental management was covered in Section C of the questionnaire. Ninety per cent of the foundries have a quality management system but only a third have an environmental management system (EMS), although 50% of those without are working towards ISO 14000. All of the larger organisations were encouraged by their major customers to have an EMS.

Section D of the questionnaire sought companies' perceptions of the energy efficiency of their metal melting processes and energy management policies. Only 40% of the foundries have an 'energy manager' or a person responsible for energy management. Thirty per cent claimed that their metal melting operation is energy efficient, two thirds rated their efficiency as 'average', the remainder admitted that their efficiency is low. The chart (Figure 4.5) shows respondents' assessment of their energy efficiency categorized by monthly output. The majority of smaller foundries considered their melting efficiency to be 'high' or 'average'. Indeed, all of the companies with less than 20 employees believed their melting system to be highly efficient. Three quarters of companies admitted that they could improve their energy efficiency; thirty per cent indicated that it could be achieved by better planning, 27% by implementing minor changes, but 36% said that they would need to install new furnaces. Of course installing new furnaces does not guarantee better energy efficiency – good furnace *management* is also necessary. Since only four contributors considered their energy efficiency to be poor, it may be assumed that the majority of foundries believe their efficiency to be acceptable.

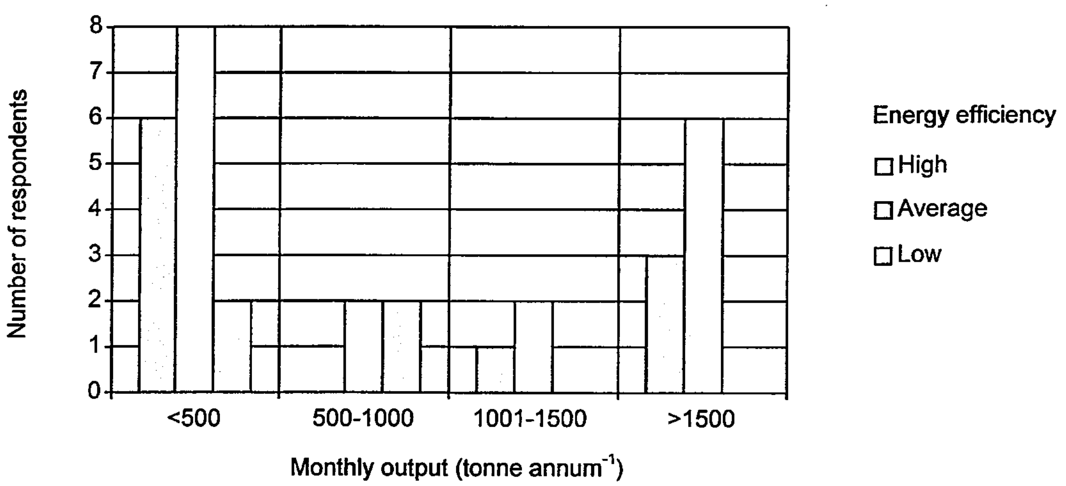


Figure 4.5. ***Energy efficiencies claimed by respondents - categorized by their output.***

Broader environmental issues were covered by questions in Section E. The majority were aware of the threat of enhanced global warming and climate change, and were aware of the EU and UK commitments to reduce GHG emissions – particularly CO_2. However, less than 40% felt that their firms could make a meaningful contribution to emissions reduction and only 27% had any intention of trying.

All but one respondent knew of the then proposed climate change levy. Companies were asked how they would respond to the financial impact of the climate change levy. Sixty-seven percent saw improving energy efficiency as the only way to offset the increased cost, while 30% said that they would increase their selling prices.

At the time, UK industrial *electricity* prices were around the middle of the ranges of the EU and G7 countries, and industrial *gas* prices were the lowest in the EU, and second lowest of G7 countries. (DTI, 2000). However, half of the foundries believed that UK industrial energy prices are higher than those of foreign competitors.

Almost 90% thought higher energy prices and/or a tax would encourage energy efficiency projects within their organisation but 24% did not consider that price rises or tax would influence energy efficiency in British industry as a whole.

Only 30% knew of the government's deliberations on tradable emissions permits. Eighteen per cent were aware of the proposals for an emissions trading scheme but none of them understood the mechanism.

Interviews

Formal interviews were conducted with people in aluminium foundries and organisations closely involved with the sector, such as suppliers, researchers, trade bodies and consultants. During site work for the case studies, there were many opportunities to informally interview people 'on the foundry floor' to whom access would not normally have been possible.

Opinions were invited on what actions, if thought to be needed, could be taken to encourage industry's acceptance of the need to reduce the environmental impacts of manufacturing processes – material and energy waste, and emissions. Responses varied, but in general it was agreed that some action was required. Several felt that there was scope for modifying casting processes, that mould yields could be higher and basic operating procedures could be changed to save energy and reduce scrap. The consensus was that education is essential if the issues of waste and emissions are to be taken seriously. Some argued that only cost incentives would drive strategies for any kind of environmental improvements.

There was a view that since profit margins were generally low, the foundry industry needs government funding for environmental improvement programmes. It was suggested also that there should be other financial 'assistance' such as tax relief for capital investments for environmental improvement.

Participants were invited to comment on the type of economic instruments that would penalize polluters and organisations that did not make efforts to avoid unnecessary waste. Interviewees favoured government grants, or suggested that financial incentives should be offered to those companies that show commitment to environmental improvement and meeting statutory requirements. Several proposed that there should be *heavy* penalties imposed upon those that failed to meet environmental regulation to 'ensure a level playing field'.

The interviewees that were not employed directly in the cast metals sector had extensive knowledge of it. This informed group included people at ETSU, EA Technology (formerly Electricity Council Research Establishment) and Energy Services (energy supplier). There was a common view that in reality, there is a low level of awareness on environmental matters, and that an integrated policy for energy and environmental issues was needed; some form of carbon tax was the most favoured economic instrument as it would be both direct, (polluter pays principle), and easy to apply.

There is ample evidence from this author's work and that of others, to indicate that SMEs need the greatest attention to encourage commitment to environmental improvement. Holti *et al.,* (1997) investigated the forces that hinder or discourage the take-up of energy-efficient technologies within manufacturing processes. Part of the research involved an assessment of national contexts affecting company-level decision-making. Case studies focused on understanding the external influences and internal organisational processes that have facilitated the adoption of various kinds of energy efficient process technologies relevant to particular sectors, the issues that were addressed, and the approaches adopted for doing so.

Holti's project was concerned with the implications for regional, national and European Union policies intended to encourage rational use of energy within industry. The project's aim was to contribute to the understanding of non-technological barriers and incentives affecting industrial take-up of new energy technologies. The researchers found that understanding these barriers would provide ways to identify the hidden costs of investment in advanced energy technologies, which apparently inhibit their take-up. It was concluded that understanding the hidden organisational costs, should enable governments to devise policies to help industry to overcome them.

The work of Talbot (2002) revealed that although technologies exist that would reduce organisations' energy consumption by 15% or more, with financial returns at least as good as can be achieved from their mainstream activities, investment in energy efficiency measures by UK companies is lower than would be expected. Talbot lists the non-financial barriers that must be overcome as:

- the low priority given to energy efficiency in most organisations;
- ensuring that investment appraisal standards used are appropriate;
- ensuring investment decisions are taken at the right level in an organisation.

Talbot identified the financial barriers as:

- there are few full-time energy managers; and
- most companies treat energy as an overhead and budget it as such, rather than understanding where energy costs arise from and why.

A study by Baylis *et al.,* (1997) of more than 400 manufacturing and process companies in South Wales revealed that in contrast to the behaviour of larger companies, there was a rather indifferent attitude to environmental impacts among SMEs. It was found also, that few small companies recognized energy losses as waste and almost 75% were not considering implementing any form of environmental management system. It concluded that SMEs should be treated differently from larger organisations.

Baylis conceded that others also had found that SMEs lag behind large companies in their understanding and approach to environmental management. Large companies were more aware of environmental obligations partly because stakeholder pressures on them are greater than on SMEs. Environmental tools such as audits, reviews, policies and implementation programmes were found to be much more common in large companies than SMEs. The study revealed that 54% of SMEs and 70% of large organisations with written environmental policies were motivated to make environmental improvements by those policies. Despite supporting evidence from case studies and other promotions, only 21% of SMEs and 50% of large enterprises believed that environmental improvements give cost savings.

The report suggests that sustainable development has yet to be addressed or reflected in the operations of most companies. Although more than half agreed that concern for the environment is an issue of long term survival of business, such concern must not jeopardize short-term profits.

Baylis *et al.,* concluded that most companies reacted to environmental regulation which was the most commonly accepted and effective stimulus for improvement irrespective of company size. But the amount of existing regulation that applies to SMEs is much less than for large companies. It is argued that this is an important reason for poor environmental performance of SMEs and suggests that improvements might be achieved through the use of more *force* than persuasion.

Government statistics (DTI, 1999a), classify 99% of UK companies as SMEs, employing 56% of the UK working population (excluding government institutions) and 50% of business turnover (excluding the financial sector). Eighty-eight per cent of all UK foundries are SMEs. (Knight Wendling, 2001). Eighty-two per cent of the respondents to the author's questionnaire to the aluminium casting sector were SMEs.

Before a company takes up an environmental improvement policy, it has to be convinced firstly that improvements are necessary. Customers can apply some pressure to implement environmental improvement programmes. For this pressure to originate from customers there must be an increased awareness of the need for environmental improvement *throughout* the supply chain. However, to encourage improved environmental performance, the information given must be sensitive to the circumstances of individual firms and should recognize that they are subject to different levels and types of internal pressure and all may not necessarily gain the same benefits.

Encouraging environmental management in SMEs is now probably one of the most important challenges for government. A study of the uptake of environmental initiatives commissioned by Groundwork, (1998) found that many managers are unaware of the key areas of environmental legislation which affect their companies. Therefore, it is reasonable to assume that if they are unaware of mandatory requirements, then they are unlikely to be aware of non-regulated environmental issues. Since according to Groundwork, SMEs use 60% of the energy attributed to the business sector, the contribution of SMEs is crucial to the government's aims to reduce carbon emissions. (Cavenagh: 1998) It is important that government agencies target SMEs with appropriately designed initiatives. The majority of SMEs are managed by entrepreneurs or accountants. Their main objective is to generate profit and are unlikely to implement non-profit making initiatives without some external pressures to do so.

These statistics emphasize the importance of the contribution by SMEs to the UK economy, *and* the potential for energy saving policies. According to Groundwork, small firms are proportionately the biggest polluters in the country. Unlike large organisations that are forced to comply to controls and regulations to satisfy regulators, their investors and customers, smaller companies claim they have neither the time nor the resources to invest in their environmental impact. However, many SMEs found that having environmental credentials helps them when tendering for new business.

An analysis of the Groundwork study shows that of the respondents:

- 99.8% of UK firms have nine employees or less;
- 25% were unable to name any environmental legislation or regulation which directly affected their company;
- 20% thought that greater green legislation would increase costs but some believed that more business would be generated;

- 42% predicted an increase in the social acceptability of their products over the next five years, [one assumes because they will be produced in an environmentally acceptable manner];
- 45% of respondents considered that having an environmental policy brings or would bring commercial benefits;
- among the benefits, around 20% of SMEs thought that 'better customer relations and/or company image would be the main commercial advantage;
- 12% of respondents claimed that they already made financial savings from improving their environmental performance.

ETSU, *et al.*, (1998), found that industry in general is becoming increasingly aware of the benefits of environmental improvement, even though environmental issues are low on the corporate agenda. It was claimed that there was "definitive evidence that environmental engagement is very often a function of company size" (p. 7) – larger companies (those employing more than 250 persons), were nearly twice as likely to have experienced the commercial advantages of environmental improvement compared to small companies (employing up to 100). Small companies were also far less likely to be motivated to take action to meet environmental legislation alone. Only two thirds of the industrial sites covered accepted that their activities *had* an environmental impact, but generally larger companies understood it better.

Discussing research carried out by Price Waterhouse in conjunction with the Universities of Warwick and Wolverhampton, Faers, (1998) said that more and more large businesses are committed to environmental management as an essential part of their commercial relationship with major long term suppliers. It was claimed that the research shows that the introduction of an energy efficiency scheme into a small company often brings benefits beyond the immediate effects of energy saving, including a general boost to staff attitude to environmental matters. Researchers from Warwick and Wolverhampton Universities found that significant numbers of owners and managers cited community concerns and customer pressure as the drivers for a trend towards environmentalism. Compliance with regulations was given as the main reason for increasing environmental control measures. Forty per cent of companies thought that adopting a more eco-friendly stance actually saved money.

There was concern that just over a third of firms spends nothing on environmental matters. Faers concluded that the government's planned introduction of tougher legislation and taxation to curb wasteful behaviour will mean that those who face up to their environmental responsibilities will be better off in the future.

According to the ETSU study, the majority of manufacturing companies does not see the environment as a key factor affecting profitability. Only 7% of sites gave similar precedence to environment matters as they do to raw material costs, productivity and skills/manpower shortages. Cost was found to be the main barrier to improving environmental performance.

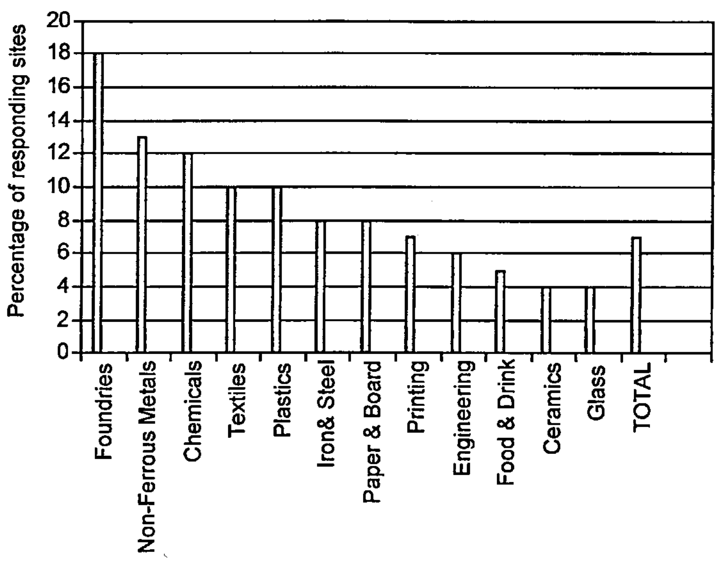


Figure 4.6. ***Sites mentioning environmental issues as a factor affecting profitability.***
(Source: ETSU, 1998)

Larger sites were found to be more likely to have some form of environmental policy (77%), but only 31% of smaller sites had. Just one in ten sites with a formal environmental management system had gained ISO 14000 accreditation; another 25% had planned to do so. ETSU's analysis showed that 18% of *foundries* mentioned environmental issues as a factor affecting profitability compared to the average of 7% for manufacturing as a whole. (Figure 4.6) The difference may be caused by the high investment and operating costs of emissions control equipment in foundries.

The majority of companies cited legislation and cost reduction as the most important motivators for environmental improvement. As would be expected, legislation was an important driver, especially in smaller companies, 53% of the sample declared that they were solely motivated by legislation. This was similar to the findings of Ramsell (1997).

4.2.3 Case studies

Case study – Foundry A

Foundry A works three shifts for five days per week and produces aluminium gravity and low-pressure diecastings. The company specializes in thin-walled components, many of which have sand cores. Fluidity and feedablity of the metal, and comprehensive running and feeding systems are critical features that determine the operating procedures that are necessary to produce good quality castings. Relatively high die temperatures must be maintained and high melt temperatures are necessary. The running and feeding systems contain a high proportion of the metal cast, as a result, mould yields are relatively low. All of these factors influence energy use and must be taken into account when assessing the scope for reducing the specific energy consumption (SEC) of the site.

Accepting that the current process parameters cannot be changed for existing products, the potential for energy saving is limited to the operation and maintenance of the melting and holding furnaces. It is on the basis of the latter that energy saving assessments will be discussed.

Equipment

A 'cell' system is operated in Foundry A. There are five cells; each has dedicated equipment for melting, holding, casting, de-coring, trimming, fettling and pressure testing. Four cells are gravity diecasting and one cell has two low-pressure diecasting machines. When the foundry was re-organized in 1998, melting by gas combined with electricity for holding was considered to be the lowest cost option for most aluminium foundries. Each cell has a dedicated gas-fired melting furnace that supplies liquid metal to pairs of electric resistance holding furnaces. (Figure 4.7)

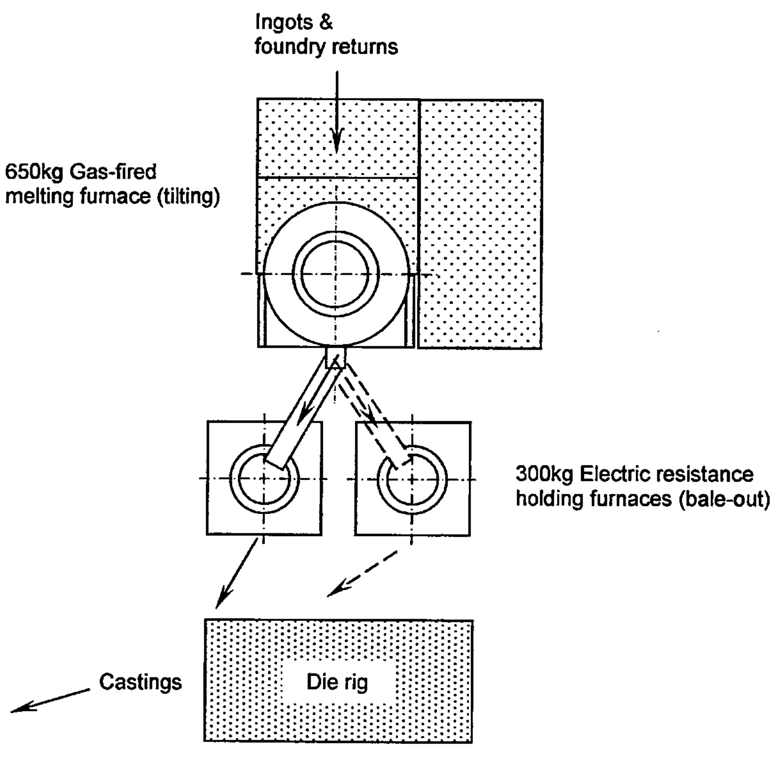


Figure 4.7. ***Layout of Cell 3 in Foundry A.***

Cell 3 was selected for the study as it produces a representative range of the company's gravity diecastings. Operating practices are similar throughout the foundry.

A 650 kilogramme (kg) capacity gas-fired tilting crucible furnace is used for melting. The furnace has a maximum heat input of 395 kW. (This is equivalent to 40 $m^3 h^{-1}$ of natural gas).

Liquid metal is transferred from the melting furnace by launder to a pair of 300 kg capacity electric crucible holding furnaces. When installed, each holding furnace was rated at 48 kW, however, when the study was made, furnace No. 1 had defective heating elements giving a maximum power input of 25 kWh h^{-1}, and furnace No. 2 drew 43 kW on full power.

Operating procedure

The holding furnaces are used alternately on a two hour cycle. By leaving a 50% 'heel' of liquid metal, (the quantity of residual molten metal when re-charged), the time to stabilize the melt temperature after re-filling is reduced. One holding furnace is dispensed, (by hand ladle), whilst the other is refilled and treated by the addition of chemicals in granular and tabular form, and master alloys as rods. Typical treatments are for degassing the melt, fluxing, promotion of grain refinement, and modification of the solidified structure. The requirements for each product are specified on the operators' process sheets.
Approximately 160 kg of aluminium are cast from one furnace before changing to the other.

Findings – Foundry A

Output

The production rate ranged from 65.4 kg h^{-1} to 83.6 kg h^{-1}. The peak output recorded was 96.5 kg h^{-1} but this was achieved only by one diecaster, and the rate could not be maintained for a full shift. During the period of the survey, casting mould yields ranged from 31% to 55%. A typical thin-walled diecasting is depicted in Figure 4.8.

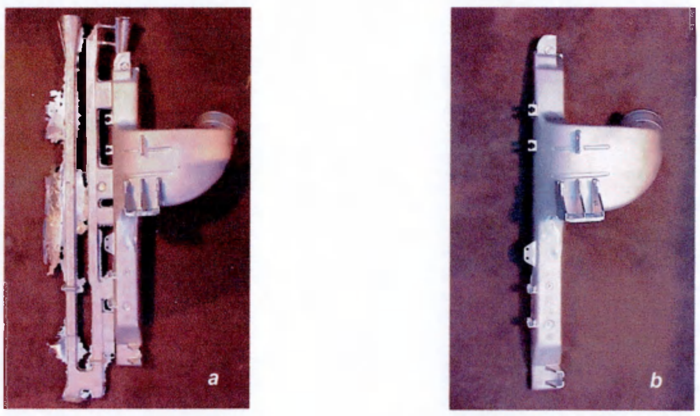


Figure 4.8. ***Typical gravity diecasting from Foundry A, a) as cast (27 kg), b) trimmed (11kg).***

Melting furnace

When on high fire, the fuel input rate to the melting furnace varied from a low of 370 kWh_p h^{-1} during peak gas demand for the site, rising to 426 kWh_p h^{-1} when gas demand for other equipment dropped. The average high-fire rate was 418 kWh_p h^{-1} (40.8 m^3 h^{-1}). This is close to the furnace manufacturer's specification of 395 kWh_p h^{-1}.

Table 4.2. ***Foundry A melting furnace data.***

		Day 1	Day 2	Interval	Day 3	Weekend	Day 4	Day 5	Total
Output	kg	2040	2083		2179		0	1188	7490 kg
Gas used	m^3	511	526		498		43	479	2057 m^3
Energy used	kWh_p	5242	5396		5108		441	4914	21 101 kWh_p
SEC	kWh_p $tonne^{-1}$	2570	2590		2344			4136	2817 kWh_p $tonne^{-1}$

During the five days when detailed data was collected, 7.49 tonnes were cast, using 21 101 kWh_p of natural gas, i.e. 2817 kWh_p $tonne^{-1}$. (Table 4.2) The total energy consumption for *nine* working days was recorded also and the production records were used to estimate the amount of metal melted. During the nine day period, the furnace used 46 000 kWh_p of gas to melt an estimated 14.5 tonnes of aluminium alloy. This corresponds to 3172 kWh_p $tonne^{-1}$ of metal cast, including the energy used during non-productive periods for die changes and unscheduled stoppages caused by die problems.

Cell 3 melting furnace did not have a thermocouple for controlling the temperature of the melt. Instead, the burner was controlled from a shrouded thermocouple outside the crucible in the heating chamber. The controller was set at 800°C and gave a fairly good control of the melt temperature at 780°C when the furnace stabilized in the holding mode. However, when melting and raising the melt to pouring temperature, the thermocouple arrangement inhibited the melting capability of the furnace since it reduced the thermal head by limiting the temperature of the heating chamber. As a result, typically a charge of 330 kg took 100 minutes to raise to 770°C which is equivalent to approximately 200 kg h^{-1}, only half of the rating of 400 kg h^{-1} specified by the furnace manufacturer.

The energy used in the furnace for melting and raising to pouring temperature (770°C - 780°C) ranged from 1916 kWh_p $tonne^{-1}$ to 2210 kWh $tonne^{-1}$, compared to the manufacturer's figure of approximately 970 kWh_p $tonne^{-1}$ to 720°C. The heat losses to maintain the temperature of the liquid metal at 770°C amounted to 189 kWh_p h^{-1}, compared with the furnace manufacturer's specified holding losses of 120 kWh_p h^{-1} for a melt temperature of 770°C.

The overall efficiency of Cell 3 melting furnace was 18%. The main reasons for such low energy efficiency are:

1) When in the holding mode for long periods, the temperature of the heating chamber stabilizes at an equilibrium level at which the energy input balances the heat losses - in this case 20°C above the molten bath temperature. When the furnace is recharged with solid material, the thermal mass of the heating chamber must be heated to at least 400°C above the desired bath temperature to give a reasonable rate of heat transfer to the charge. The time lag to achieve the temperature head inhibits the melting rate.
2) The furnace is designed for waste heat recuperation by pre-heating the charge with exhaust gases directed over the solid metal before entering the crucible. This is not possible in this case because the normal charges are too small (typically 300kg) to extend into the path of the exhaust gases.
3) The furnace is too large for the demand.
4) The furnace lining is in poor condition.
5) The burner fuel/air ratio is incorrect. The exhaust gas analysis was O_2 - 8.4%, CO_2 - 7.0%, and the excess air coefficient, λ was 1.67 – indicating that the excess air supply to the burner is too high at 67%, compared with 18% during commissioning when the readings were O_2 - 3.20%, CO_2 - 9.92% and λ (defined in Section 3.5.2) - 1.18.

Holding furnaces

The temperature settings for the melt in the electric holding furnaces were 740°C or 770°C according to the operator's process sheet provided for each casting type. The actual temperatures varied between 710°C and 800°C. The causes of the temperature swing were:

1) Melt thermocouples are too short to remain immersed at lower metal levels. In this condition, the thermocouple cools below melt temperature set-point – the heaters switch on and the furnace temperature rises uncontrolled to the heating chamber set-point, overheating the melt. When the furnace is subsequently re-filled, the thermocouple is then immersed in the melt, and quickly reaches control temperature

and the power is turned off. The heat stored in the furnace lining and crucible must be dissipated – much of it into the melt which then overheats.

2) Dross build-up on the surface of the protection sheath acts as an insulator, reducing the thermocouple's sensitivity which creates a lag in the control response in the order of 15-30 minutes.
3) The temperature of the liquid charge from the melting furnace was sometimes too high, causing the heating to be off for long periods whilst the temperature fell to set-point by which time the temperature of the heating cavity had fallen well below that needed to hold the furnace in a steady state in which the heat input balances the losses.
4) The heat input on furnace No. 1 was low, causing a slow response to a call for heat.
5) Poor heat conductivity of the crucibles due to slag and dross build-up, and ageing. Dross build-up on the internal walls of crucibles acts as a thermal insulator. To maintain operating efficiency, regular cleaning (as recommended by crucible manufacturers) is important.

Silicon carbide and graphite particles in refractory crucibles give them their conductivity. As the graphite in the crucible oxidizes, conductivity falls. The rate of oxidation is a function of the temperature and time that the crucible material is exposed to air. Foundry A's practice of operating furnaces at low metal levels for long periods without covers increases the rate of oxidation from the inner wall. The efficient life-time of crucibles is limited and they should be changed when there is evidence of deterioration in temperature control or increased energy required to maintain working temperature.

The insulating covers have been permanently removed from the holding furnaces causing higher heat losses by radiation. According to the manufacturer's specification, the standing losses from the holding furnaces with a full charge at 720°C should be 6 kWh h^{-1} with covers closed, and 10 kWh h^{-1} when open. The average observed melt temperature was

755°C at which radiated heat loss from the melt surface and through the insulation rise to 12 kWh h^{-1}. However, the average holding losses from No.1 furnace were 18.50 kWh h^{-1} and from No. 2 furnace the average was 18.98 kWh h^{-1}. The high energy losses indicate defective insulation. The standing losses ranged from 16.60 kWh h^{-1} when the crucible was full, to 21.00 kWh h^{-1} when the metal was at the lowest operational level. The higher loss at lower metal levels is due to the higher radiated loss from the exposed inner wall of the crucible.

The causes of the high heat losses from the holding furnaces are those listed above for the temperature swing and:

- covers are not used when on standby;
- poor condition of the insulation.

The performance data for the holding furnaces is analysed in Table 4.3. The total electrical energy used by the two holding furnaces to maintain the metal (7.49 tonnes) at temperature was 3848 kWh – equal to 514 kW $tonne^{-1}$ cast. After converting from delivered energy to primary energy using a conversion factor of 2.6, (DEFRA, 2001), this is equivalent to 1336 kWh_p $tonne^{-1}$ as cast. (Table 4.4).

Table 4.3. ***Foundry A holding furnaces data.***

		Day 1	Day 2	Interval	Day 3	Weekend	Day 4	Day 5	Total
Output – gross	kg	2040	2083		2179		0	1188	7490 kg
Output – net	kg	785	937		893		0	367	2982 kg
Mould yield	%	38	45		41			31	40 %
Energy input	kWh	834	896		762		438	918	3848 kWh
Primary energy	kWh_p	2168	2330		1981		1139	2387	10 005 kWh_p

Table 4.4. ***Summary of Findings – Foundry A.***

Energy to melt	2817 kWh_p tonne^{-1}
Holding energy	1336 kWh_p tonne^{-1} cast
Holding energy	3355 kWh_p tonne^{-1} (trimmed)
SEC Cell 3	**4153 kWh_p tonne^{-1} (as cast)**
	6172 kWh_p tonne^{-1} (trimmed)

Case study – Foundry B

Foundry B is a precision sand casting foundry using the 'core assembly technique'. Except for automated low-pressure sand casting – such as the 'Cosworth' process, precision sand casting is an intermittent process whereby sand moulds are produced in batches. This requires charges of molten metal to be available to match the capacity of a batch of moulds. The foundry operates 115 hours per week, commencing at 1800h on Sunday and finishing at 1300h on Friday.

There are two casting areas in the foundry – one is referred to as the 'production' foundry and is dedicated to casting a few patterns of high volume products; the other area produces small batches of various casting in lower volumes. Casting weights range from 2 kilogrammes to 100 kilogrammes, mainly in LM25 alloy. Foundry B's production foundry was studied to find the current energy intensity of the melting and holding process. The metal melting régime is similar throughout the foundry – namely, aluminium is melted in gas-fired furnaces and transferred to electric holding furnaces.

Castings made at Foundry B are complex and require comprehensive running and feeding systems to ensure high integrity. As a consequence, mould yields range from 40% to 55%.

Figure 4.9. ***Typical Foundry B sand mould with double pouring cups (sprues).***

An example of an assembled mould is shown in Figure 4.9. The metal is superheated in the holding furnaces to allow for temperature loss upon transfer to the casting ladles. The casters carefully control pouring temperatures.

Equipment

Two gas-fired crucible furnaces are used for melting. One furnace (Furnace F) has a capacity of 650 kg, the other – Furnace H has a capacity of 800 kg. The maximum rated fuel input for each furnace is 395 kW. The maximum melting rate of each furnace is 400 kg h^{-1} for a melt temperature of 720°C. Liquid metal is transferred from the melting furnaces via launders to a pair of electric resistance holding furnaces, one rated at 72 kW, the other 80 kW. The general layout is depicted in Figure 4.10.

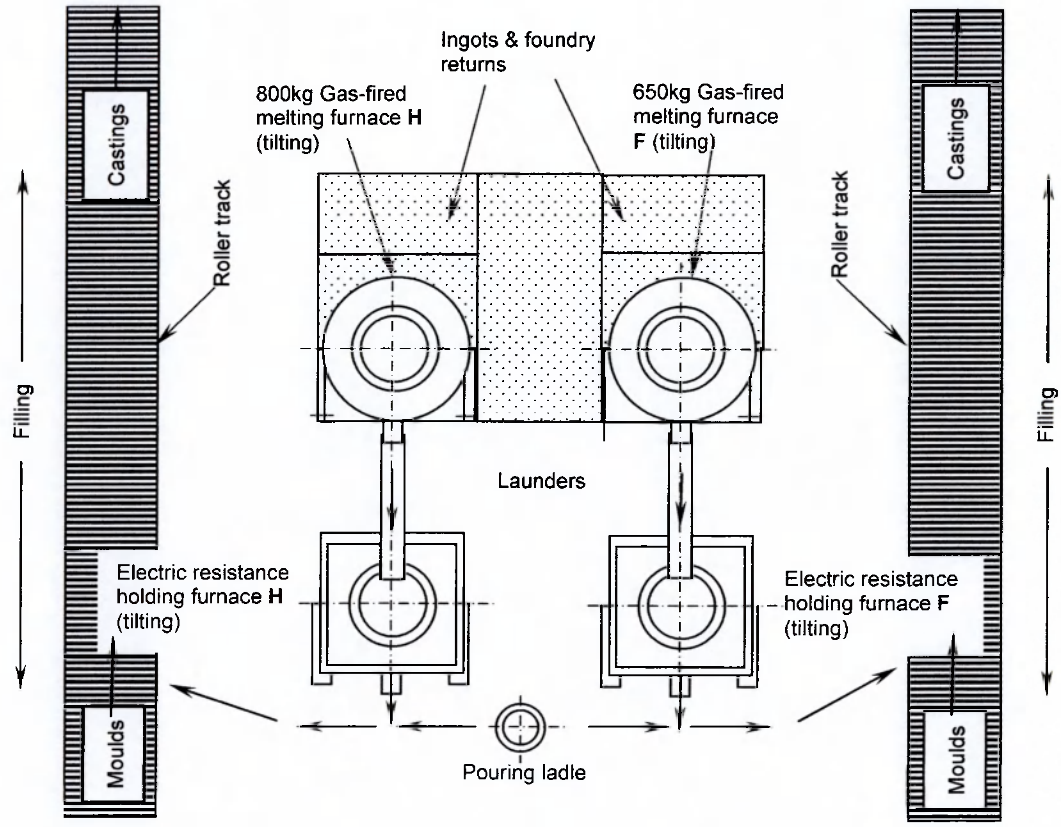


Figure 4.10. ***Diagrammatic arrangement of 'production foundry' furnaces at Foundry B.***

Operating procedure

Metal is melted and raised to a temperature range of 780°C to 800°C. It is held at this temperature until needed to refill the electric holding furnaces. The melting furnaces are re-charged after each transfer to the holding furnaces.

The temperature of the melt in the holding furnaces is stabilized at 780°C and degassed by introducing nitrogen through a rotary degassing machine. Alloying additions and chemical treatments are made in the holding furnaces, in accordance with the operators' procedure sheet. After treatment, the metal is discharged into casting ladles in which the metal is skimmed and held until the temperature has dropped to the prescribed casting temperature of 740°C. The operators use a dip-thermocouple connected to a hand-held digital pyrometer to measure the temperature.

It is current practice to fill both holding furnaces at the end of the week, (Friday 1300h) and hold at 780°C until the start of the next shift at 1800h on Sunday.

Findings – Foundry B

Melting furnaces

Table 4.5a. ***Foundry B data – Melting Furnace F.***

		Day 1	Day 2	Day 3	Day 4	Day 5	Weekend	Total
Output	kg	4363	3680	3122	2719	755	974	15 613 kg
Gas used	m^3	729	669	581	514	24	228	2745 m^3
Energy used	kWh	7478	6863	5960	5273	250	2335	28 159 kWh
SEC	kWh_p $tonne^{-1}$	1714	1865	1909	1939	331	2397	1804 kWh_p $tonne^{-1}$

Table 4.5b. ***Foundry B data – Melting Furnace H.***

		Day 1	Day 2	Day 3	Day 4	Day 5	Weekend	Total
Output	kg	2724	3680	3912	3513	1292	1081	16 202 kg
Gas used	m^3	514	651	673	659	96	226	2819 m^3
Energy used	kWh	5273	6678	6904	6760	984	2318	28 917 kWh
SEC	kWh_p $tonne^{-1}$	1936	1815	1765	1924	762	2144	1785 kWh_p $tonne^{-1}$

The Foundry B study was made over 168 hours, which included the non-production time between the last shift at the end of the working week and commencement of the following week. During the period of the tests, Furnace F melted 16.2 tonnes using 28 917 kWh_p of gas, Furnace H melted 15.6 tonnes with 28 159 kWh_p. (Tables 4.5a & 4.5b) The energy consumptions were 1785 kWh_p $tonne^{-1}$ and 1804 kWh_p $tonne^{-1}$ respectively, giving an average SEC of 1794 kWh_p $tonne^{-1}$ for melting.

Since the heat content of aluminium at 780°C is 340 kWh $tonne^{-1}$, (Appendix IV) the figures indicate that the overall energy efficiency of the melting system, (Furnaces F and H) is only 19%. Therefore, the energy used is 58% higher than that specified by the furnace manufacturer.

The melting furnace combustion systems are designed to work at a dynamic supply pressure of 20 mbar. During the study the furnaces could not operate at maximum fuel input on high fire because the gas supply pressure was unstable and at times inadequate, falling to 15 mbar. As a result, the gross energy input varied. The maximum input to the Furnace H was 390 $kWh_p\ h^{-1}$ and to Furnace F – 346 $kWh_p\ h^{-1}$. However, when the gas pressure fell, the combustion system could not adjust the fuel/air ratio sufficiently to compensate. Under this condition, the excess air rose from approximately 30% to 50%.

Apart from the effects caused by the irregular gas supply to the burners, the variations in the measured efficiencies are due also to variations in the weight of charge and the size of the liquid metal heel, the type of charge (proportion of ingot to returns and bulk density of returns), and the time that the furnace was in the holding mode prior to pouring. (After a prolonged holding time, more energy is used to raise the furnace mass to working temperature).

The data collected showed that the efficiencies of the melting furnaces are within the furnace manufacture's specifications. The relatively high SEC is due to low utilization of the furnaces. Another adverse factor was created by the unstable gas supply pressure, which does not allow the furnaces to be set up for optimum combustion efficiency under all conditions.

Output - Holding furnaces

During the survey, 30 charges were processed in the 80 kW furnace, and 27 charges in the 72 kW furnace using 4824 kWh and 3641 kWh respectively. For comparison purposes, the reduction achieved by the test made on the 72 kW unit (see below) must be added giving a total of 3798 kWh. The differences between the two furnaces are due to several variable factors:

- as the metal level falls, holding losses rise due to increasing heat radiation from the exposed inner wall of the crucible;
- temperatures of molten charges vary between 780°C and 800°C;
- heat is lost to the degassing machine rotor, and nitrogen passing through the melt extracts heat from the melt, which has to be replaced.

According to the furnace supplier, for a melt temperature 720°C, the standing losses should be in the order of 8 kWh h^{-1} when closed and 18 kWh h^{-1} when open. At 780°C, the closed losses rise to approximately 9 kWh h^{-1} and open losses to 20 kWh h^{-1}. When delivered, the holding furnaces were equipped with covers, but these had been removed permanently, as they would have interfered with the metal transfer launders. During the five working days, the average standing losses were 22.5 kWh h^{-1} from the 80 kW unit and 19.8 kWh h^{-1} from the 72 kW furnace.

Table 4.6a. ***Foundry B data – Holding furnace F.***

		Day 1	Day 2	Day 3	Day 4	Day 5	Weekend	Total
Output – gross	kg	4810	5669	3122	2719	755	1081	18 156 kg
Output – net	kg	2089	2919	1585	1382	350	523	8848 kg
Mould yield	%	43	51	51	51	46	48	49 %
Energy input	kWh	666	704	848	707	628	1271	4824 kWh
Primary	kWh_p	1732	1830	2205	1838	1633	3305	12 542 kWh_p

Table 4.6b. ***Foundry B data – Holding furnace H.***

		Day 1	Day 2	Day 3	Day 4	Day 5	Weekend	Total
Output – gross	kg	2280	1691	3912	3513	537	974	12907 kg
Output – net	kg	914	801	1944	1786	295	426	6166 kg
Mould yield	%	40	47	50	51	55	44	48 %
Energy input	kWh	607	700	552	524	332	936	3651 kWh
Primary	kWh_p	1578	1820	1435	1362	863	2434	9493 kWh_p

Table 4.7. ***Summary of Findings – Foundry B.***

SEC via Holding furnace F	2485	kWh_p $tonne^{-1}$ (as cast)
	3212	kWh_p $tonne^{-1}$ (trimmed)
SEC via Holding furnace H	2529	kWh_p $tonne^{-1}$ (as cast)
	3334	kWh_p $tonne^{-1}$ (trimmed)
SEC for Production foundry	**2507**	**kWh_p $tonne^{-1}$ (as cast)**
	3273	**kWh_p $tonne^{-1}$ (trimmed)**

Case study – Foundry C

Foundry C is a large pressure diecasting foundry with a small gravity diecasting facility. It is part of a multi-site aluminium diecasting company employing more than 600 people of whom approximately 200 are employed at this site. The site output is approaching 4000 tonnes of trimmed castings per annum. Casting weights range from 5 grammes to 5 kilogrammes. The company supplies fully machined castings to the automotive, white goods and engineering markets with the automotive sector accounting for 80% of business. The foundry operates eight 9½ hour shifts per week, plus overtime when necessary to meet demand.

Equipment

The company has 19 high-pressure diecasting machines with locking forces ranging from 200 to 750 tonnes. There is also a small gravity diecasting section.

For pressure diecasting, aluminium is bulk-melted in twin-chamber gas-fired reverberatory furnaces, gas-fired tilting crucible furnaces, electrical induction furnaces, and an electrical resistance radiant-roof furnace. The unusually wide variety of melting furnaces is due to the past availability of energy supplies and their historical costs. Until recently, there was no natural gas supply to the region. The options were oil, LPG and electricity. Oil was not convenient for environmental reasons and LPG was more expensive than electricity. To take advantage of low night-time electricity tariffs, induction furnaces were installed to melt metal during the night. This metal was stored in the large electric resistance holding furnace for casting during the day.

When natural gas became available, it was more economical to use that for melting and use electricity for holding only. The foundry has expanded recently; it is planned to install more gas-fired melting equipment to replace the induction furnaces.

During the study, approximately 85% of the molten metal required for pressure diecasting was supplied from the two gas-fired reverberatory furnaces. One furnace, (S1) has an output capacity of one tonne per hour with an energy rating of 1000 kW. The other, (S2) is rated at 1600 kW and can melt two tonnes per hour.

Liquid metal is transferred in ladles by forklift truck from the melting furnaces to holding furnaces that are positioned at each diecasting machine. The crucible capacities of the holding furnaces range from 250 kg to 500 kg depending upon the throughput capacity of the machines and access required for the automatic ladles. Some of the holding furnaces are heated by gas burners, others by electrical elements. The system is shown in the flow diagram Figure 4.11.

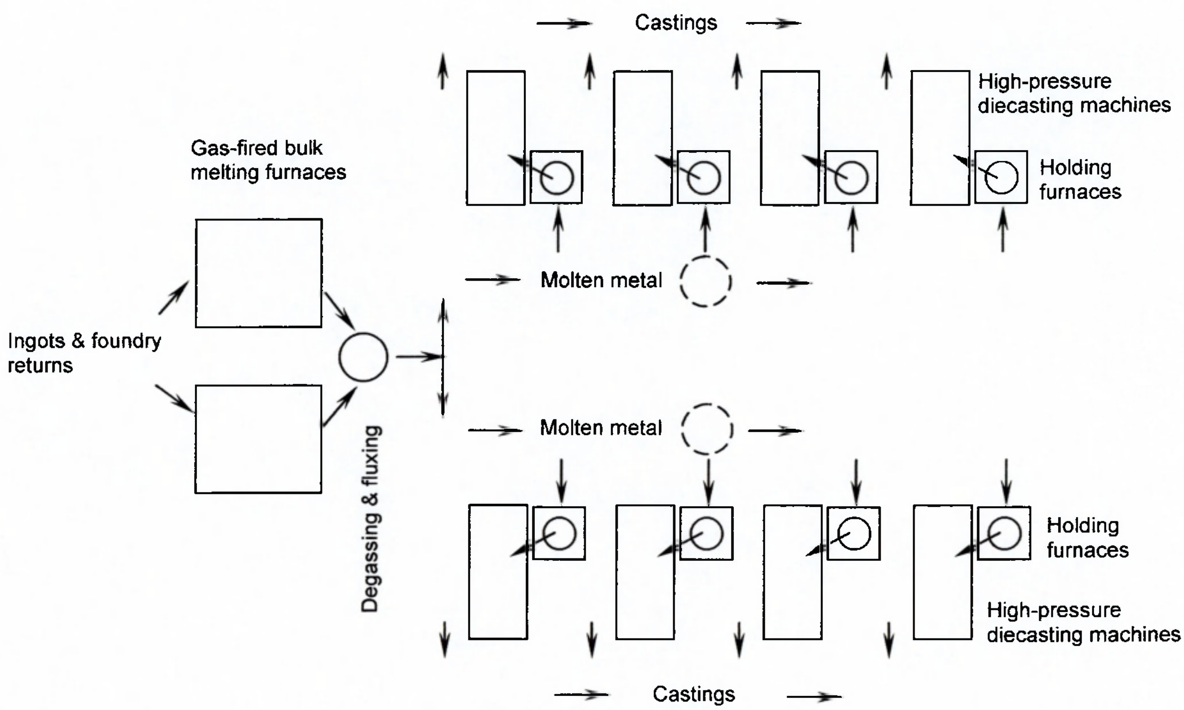


Figure 4.11. ***Flow diagram of pressure diecasting foundry.***

The three pressure diecasting stations used for the study were selected by Foundry C's production director to give what he considered would be the most representative data from the facilities.

Both reverberatory furnaces have existing meters in the gas supply pipes. The gas-fired holding furnaces are not equipped with meters. For the study, a meter was installed on a 500 kg capacity gas-fired holding furnace feeding a 750 tonne pressure diecasting machine. Kilowatt-hour meters were connected to two 400 kg capacity electric holding furnaces on two of the 400 tonne pressure diecasting machines.

Although not in the original programme for the site, it was convenient to study also the performance of the manual gravity diecasting facility separately. The section was relatively small and the electric resistance furnaces used for melting *and* holding had existing kilowatt-hour meters. The findings from the section may be typical of many small gravity diecasting foundries.

Operating Procedure – Pressure diecasting

LM24 aluminium alloy is melted and raised to a temperature of 690°C; LM6 is heated to 680°C. After discharging into transport ladles, the metal is degassed and cleaned by introducing nitrogen and flux, molten metal is then transported to the holding furnaces which are adjacent to each pressure diecasting machine. The holding temperatures are in the range 665°C to 670°C.

Operating Procedure – Gravity diecasting

Two gravity diecasting stations with manually operated dies were in operation. These are referred to as Stations A and B for the study. Each station has a pair of 48kW electrical resistance bale-out furnaces that are operated alternately, one melting, the other holding for casting. Two dies are worked at each station. The melt temperature settings were 840°C or 800°C according to the characteristics of the castings.

Findings – Foundry C

Output – High pressure diecasting

During the 7 day survey, the one tonne furnace (S1) melted 95 tonnes of LM24 aluminium alloy and used 7303 m^3 of natural gas which equates to 790 kWh_p $tonne^{-1}$; the gross energy efficiency of the furnace was approximately 40%. The larger melting furnace (S2) was commissioned shortly before the case study was undertaken and was not being used to its maximum capacity. The furnace melted 92 tonnes of LM24 in 7 days. The gas input was 7098 m^3, giving an energy use of 794 kWh_p $tonne^{-1}$ of aluminium melted at a gross efficiency of 40%. The data, (Tables 4.8a and 4.8b), show that the efficiencies of the melting furnaces are within the manufacturer's specification.

Table 4.8a. ***Foundry C data – Melting furnace S1.***

		Day 1	Day 2	Day 3	Weekend	Day 4	Day 5	Total
Output	kg	18 000	22 000	6000		25 000	24 000	95 000 kg
Gas used	m^3	1402	1505	1237	916	676	1568	7303 m^3
Energy used	kWh	14 411	15 470	12715	9414	6949	16 117	75 076 kWh
SEC	kWh_p $tonne^{-1}$	801	703	2119		655	672	790 kWh_p $tonne^{-1}$

Table 4.8b. ***Foundry C data – Melting furnace S2.***

		Day 1	Day 2	Day 3	Weekend	Day 4	Day 5	Total
Output	kg	22 000	17 000	10 000		21 500	21 280	91 780 kg
Gas used	m^3	1185	1279	1346	875	690	1724	7098 m^3
Energy used	kWh	12 155	13 126	13 811	8975	7076	17 686	72 829 kWh
SEC	kWh_p $tonne^{-1}$	552	772	1381		747	831	794 kWh_p $tonne^{-1}$

Average SEC for melting furnaces - 792 kWh_p $tonne^{-1}$

Output – Gravity diecasting

Station A produced 1784 kg of castings, using 2132 kWh of electricity for melting which equates to 1195 kWh $tonne^{-1}$. (Table 4.11a) The average mould yield was 70%.

Station B made 1681 kg of castings and an additional 160 kg of liquid metal was melted in one of the furnaces and transferred to an adjacent automated cell. The electricity input was 3331 kWh to give 1809 kWh^{-1} $tonne^{-1}$. The figure for Station B was higher than Station A because both Station A furnaces were held full at temperature for one day during which no castings were made.

Electric holding furnaces – Pressure diecasting

During the working shift, the average electricity used by the 46 kW holding furnace on machine No. 407 was 7.8 kWh h^{-1}. (Table 4.9a). The 46 kW furnace on machine No. 408 used 7.2 kWh h^{-1}. (Table 4.9b) During the weekend, the furnaces were closed with insulated covers, reducing the standing losses to 5.4 kWh h^{-1}. The total electrical energy used over seven days was 1199 kWh on machine No. 407 and 1164 kWh on No. 408 giving an hourly average of 7 kWh per furnace.

Table 4.9a. ***Foundry C data – Machine No. 407 holding furnace.***

		Day 1	Day 2	Day 3	Weekend	Day 4	Day 5	Total
Run time	hours	12.76	10.00	2.17		16.77	7.82	49.52 hours
Output - gross	kg	1296	1242	382	0	3136	1252	7308 kg
Output - net	kg	800	532	137	0	1128	443	3040 kg
Mould yield	%	62	43	36		36	35	42 %
Energy input	kWh	189	182	49	398	206	175	1199 kWh
Primary	kWh_p	491	473	127	1035	536	455	3117 kWh_p

Table 4.9b. ***Foundry C data – Machine No. 408 holding furnace.***

		Day 1	Day 2	Day 3	Weekend	Day 4	Day 5	Total
Run time	hours	18.50	16.17	8.18		18.4	7.26	68.51 hours
Output – gross	kg	2717	2370	1101	0	2487	975	9650 kg
Output – net	kg	1661	1449	379	0	855	390	4734 kg
Mould yield	%	61	61	34		34	40	49 %
Energy input	kWh	185	176	48	425	177	153	1164 kWh
Primary	kWh_p	481	458	125	1105	460	398	3026 kWh_p

Machine No. 407 produced 7.3 tonnes of castings for which the holding furnace used 427 kWh_p $tonne^{-1}$. The total primary energy used for melting and holding was 1219 kWh_p $tonne^{-1}$ cast. The average mould yield was 42% – giving an energy consumption of 1817 kWh_p $tonne^{-1}$ of trimmed castings.

The output from machine No. 408 was 9.6 tonnes. The average mould yield was 49% and the holding furnace used 314 kWh_p $tonne^{-1}$. The total primary energy used for melting and holding was 1106 kWh_p $tonne^{-1}$ cast, and 1431 kWh_p $tonne^{-1}$ of trimmed castings.

Gas-fired holding furnace – Pressure diecasting

The gas-fired holding furnace on the 700 t diecasting machine (Machine No. 703) used 6.2 m^3 h^{-1} of natural gas on low fire and 15.5 m^3 h^{-1} when on high fire, equivalent to 64 kW and 160 kW respectively. The average holding losses were 45 kWh h^{-1} during the operating shift and 41 kWh h^{-1} when closed during the weekend.

Sixteen tonnes of castings were made on machine No. 703, using 727m^3 of gas in the holding furnace. (Table 4.9c) The energy used for holding was 461 kWh $tonne^{-1}$ cast. The total energy used for melting and holding was 1253 kWh_p $tonne^{-1}$ of aluminium cast. The mould yield was 61% giving a net energy consumption of 1543 kWh_p $tonne^{-1}$ of trimmed castings. Although the cost of gas for holding is lower than for electric holding, the primary energy used per tonne of metal cast from the gas furnace is only marginally lower.

The average energy used for holding for the 400 tonne diecasting machines was 1154 kWh_p $tonne^{-1}$ cast, and 1582 kWh_p $tonne^{-1}$ after trimming. The average energy used for pressure diecasting in Foundry C was 2316 kWh_p $tonne^{-1}$ of trimmed castings.

Table 4.9c. ***Foundry C data – Machine No. 703 holding furnace.***

		Day 1	Day 2	Day 3	Weekend	Day 4	Day 5	Total
Run time	hours	15.16	13.33	4.85		14.32	13.57	61.23 hours
Output - gross	kg	3993	3536	1278	0	3771	3591	16 169 kg
Output - net	kg	2453	2172	785	0	2317	2206	9933 kg
Mould yield	%	61	61	61		61	61	61 %
Gas used	m^3	101	91	26	267	130	114	727 m^3
Energy used	kWh_p	1032	930	264	2736	1333	1165	7459 kWh_p

Table 4.10. ***Summary of Findings – Foundry C – Pressure diecasting foundry.***

Average SEC for 400 t machines	1154 kWh_p $tonne^{-1}$ (as cast)
	1582 kWh_p $tonne^{-1}$ (trimmed)
SEC for 700 t machine	1253 kWh_p $tonne^{-1}$ (as cast)
	1543 kWh_p $tonne^{-1}$ (trimmed)
SEC for Pressure diecasting	**1203 kWh_p $tonne^{-1}$ (as cast)**
	1557 kWh_p $tonne^{-1}$ (trimmed)

Electric melting and holding furnaces – Gravity section

The gravity section was operating for a single shift of 9½ hours per day – Monday to Thursday, and 6 hours on Friday. For the study, electricity use and casting output were recorded for four operating days with a weekend shutdown between them.

According to the manufacturer's specification, the furnace standing losses with a full charge at 720°C are 3.3 kWh h^{-1} with an insulated cover, and 8.8 kWh when open. However, the furnace covers had been removed. At 800°C melt temperature the heat loss from an open furnace should be in the order of 12 kWh h^{-1}. The average holding losses measured during the study were 15 kWh h^{-1} at 800°C and 16 kWh h^{-1} at 840°C, indicating that the furnace linings needed repair.

The energy used for gravity casting was 3906 kWh_p $tonne^{-1}$ cast. The average mould yield was quite high at 71%, giving a net SEC of 5801 kWh_p $tonne^{-1}$ of trimmed castings.

Table 4.11a. ***Foundry C data – Gravity Section – Station A.***

		Day 1	Day 2	Day 3	Weekend	Day 4	Day 5	Total
Operating time	hours		9.50	6.00	0	9.50	9.50	34.5 hours
Output - gross	kg		320	255	0	580	629	1784 kg
Output - net	kg		241	191	0	391	424	1247 kg
Mould yield	%		75	75		67	67	70 %
Energy input	kWh		327	227	0	886	692	2132 kWh
Primary	kWh_p		850	590	0	2304	1799	5543 kWh_p

Table 4.11b. ***Foundry C data – Gravity Section – Station B.***

		Day 1	Day 2	Day 3	Weekend	Day 4	Day 5	Total
Operating time	hours		9.50		0	9.50	9.50	28.5 hours
Output – gross	kg		413		0	520	588	1681 kg
Output – net	kg		328		0	414	468	1210 kg
Mould yield	%		79			80	80	72 %
Energy input	kWh		923		0	1472	936	3331 kWh
Primary	kWh_p		2400		0	3827	2434	8661 kWh_p
Transferred to Auto Cell	kg					160		

Summary of Findings – Foundry C – Gravity diecasting foundry

SEC for Gravity diecasting - 3906 kWh_p $tonne^{-1}$ (as cast)
- 5801 kWh_p $tonne^{-1}$ (trimmed)

Based on Foundry C's process mix for 2000, the average SEC for melting and holding would be 1357 kWh_p $tonne^{-1}$ as cast, and 1802 kWh_p $tonne^{-1}$ trimmed.

Findings summary

The primary energy used for melting and holding by each of the host foundries varied widely. As Table 4.12 shows, the energy used – ranged from 1203 to 4153 kWh_p $tonne^{-1}$ cast. The reasons for the variation have been explained by the different types of melting furnaces used and the operating régimes employed.

Table 4.12. ***Summary of case study findings.***

Site	Energy used $tonne^{-1}$ as cast (kWh_p)	Energy used $tonne^{-1}$ trimmed (kWh_p)
Foundry A	4153	10 431
Foundry B	2507	3273
Foundry C – Pressure diecasting	1203	1557
Foundry C – Gravity diecasting	3906	5807
Foundry C - Overall	1357	1802

There was an even greater disparity when comparing the energy used per tonne of trimmed castings. The table show that this ranged from 1557 kWh_p $tonne^{-1}$ to more than six times at 10 431 kWh_p $tonne^{-1}$. Two factors influence the primary energy used when related to trimmed castings – mould yield and the proportions of gas and electricity used for melting and holding. The highest figure is from Foundry A where average mould yields are low and a high proportion of electrical energy is used. Conversely, Foundry C's low energy requirement per tonne of trimmed castings is due to the relatively high mould yield and electricity represents a small proportion of the energy used for melting and holding.

Data collected and observations made during the case studies show that there are opportunities for energy waste reduction in each of the host foundries. The next section reviews the waste reduction measures that could be implemented and energy savings that could be achieved.

4.3 Measures to reduce energy waste

Energy is used for several purposes by foundries – directly in the casting process for melting and maintaining in the molten state, in secondary processes such as de-coring, sawing, fettling, heat-treatment, sand reclamation, motive power, and for site services such as lighting, ventilation and heating.

This research confirms that 10% of energy used for melting and holding could be saved without any cost, simply by better management of the production process alone. With a good energy management strategy, energy use is quantifiable and controllable so that its waste can be reduced. Often, energy efficiency and energy management is more a matter of good operating practices rather than the application of engineering principles.

4.3.1 Measures/Savings Summary – Foundry A

In 2000, Foundry A purchased 6.3 GWh (16.4 GWh_p) of electricity and 12.0 GWh of gas. In addition to metal melting and holding, electricity is used for driving pumps, compressors, cooling fans, air extraction, saws, clipping presses, machining centres, and lighting, and natural gas is used for die heating, ladle heating, space heating and water heating.

The weight of castings sold during the year was not recorded. Therefore the output of trimmed castings (before machining) was estimated from the annual purchases of aluminium ingot. 1200 tonnes of ingot were bought. After allowing for dross and spillage losses of 5%, approximately 1140 tonnes of trimmed good castings were made.

According to the foundry manager, an average of 5% of the weight of trimmed castings is removed by machining to final dimensions. On this basis, from 1140 tonnes of trimmed castings, the weight of castings despatched would be 1083 tonnes per annum.

As Table 4.4 (p. 169) shows, Cell 3 used 6172 kWh_p (22.2 MJ_p) $tonne^{-1}$ of trimmed castings – 2817 kWh_p $tonne^{-1}$ for melting and 3355 kWh_p $tonne^{-1}$ for holding. Based on the findings, the total energy used for melting and holding in Foundry A is in the order of 12 GWh_p per annum, 4 GWh_p of electricity and 8 GWh_p of gas. Therefore, approximately 56% of site energy is used for melting and holding.

The site SEC in 2000 was 40 GJ_p $tonne^{-1}$ of saleable product. For gravity diecasting foundries, ETSU (1997) reported figures ranging from 23 to 45 GJ_p $tonne^{-1}$. The industry average was updated to 37 GJ_p $tonne^{-1}$. (ETSU 2000) Foundry A's performance is lower than the industry average. This may be expected since most of the components produced have thin walls, mould yields are relatively low, reject levels are quite high, and unlike many gravity diecasting foundries, many of the castings are supplied fully machined. A detailed discussion of these factors is reserved for later in the chapter.

Potential energy saving

The gas-fired melting furnace used in Foundry A's Cell 3 is too large for the current output of the cell. There are two possible ways to raise the energy efficiency of melting here, a) use only one melting furnace to feed two cells when the same alloys are being cast, or b) install a smaller furnace.

If one furnace could be used to supply liquid metal to more than one cell, it would require a change to the company's policy of having a dedicated melting furnace so that each cell is an integrated system. It would also entail transfer of liquid metal by mobile ladles. This may not be acceptable. To install smaller melting furnaces would not be economically viable since the melting furnaces are relatively new.

The charge pre-heating facility on the melting furnaces is not used, therefore efficiency could be raised by converting them to rear flues (rear exhaust) and fitting insulated top covers. Converting to rear exhaust would reduce the radiated heat losses from the furnace heating chamber by closing the annular opening between the crucible rim and the top cover of the furnace that was designed to allow charge preheating by the exhausting gases. The furnaces should then be open only when charging, and when cleaning the crucibles. These changes would reduce energy use by lowering the radiated losses from the combustion chamber, from the crucible inner wall and from the surface of the melt.

According to the furnace manufacturer, converting the exhaust arrangement would save 40 kWh h^{-1}. Based on radiated heat loss measurements made at Foundry B, the use of a cover when convenient would save approximately 33 kWh h^{-1}. If the cover were closed for 80% of the operating shift, there would be a saving of 1400 kWh of gas per day – equivalent to 30% of the present input.

Using covers on the electric holding furnaces when access to the crucible is not required would reduce the standing losses. During the study, the average energy losses were approximately 19 kWh h^{-1} for each furnace. By re-instating the swing-aside covers that were supplied with the furnaces, the losses could be reduced by 50% (approximately 9.5 kWh h^{-1}) when the furnaces are not being baled-out. Allowing five minutes for re-filling and about ten minutes when the charge is being treated prior to casting, the cover could be closed for 75% of the working shift. This would save 100 kWh of electricity per day – 11% of electricity used in each of the gravity diecasting cells.

Using more sensitive thermocouples would reduce the temperature swing allowing lower holding temperatures to be used to give further energy saving. Dross build-up on the inner walls of crucibles also contributes to poor temperature control. Regular cleaning would reduce this effect.

Foundry A savings summary

Conversion of melting furnace – 1400 kWh of gas per day.

Covers on holding furnaces – 100 kWh/day of delivered electrical energy equivalent to 260 kWh_p/day.

Average daily energy use in Cell 3 – (21 101+10 005)/5 = 6201 kWh_p.

Potential saving – (1400+260)/6201 = 26.7%.

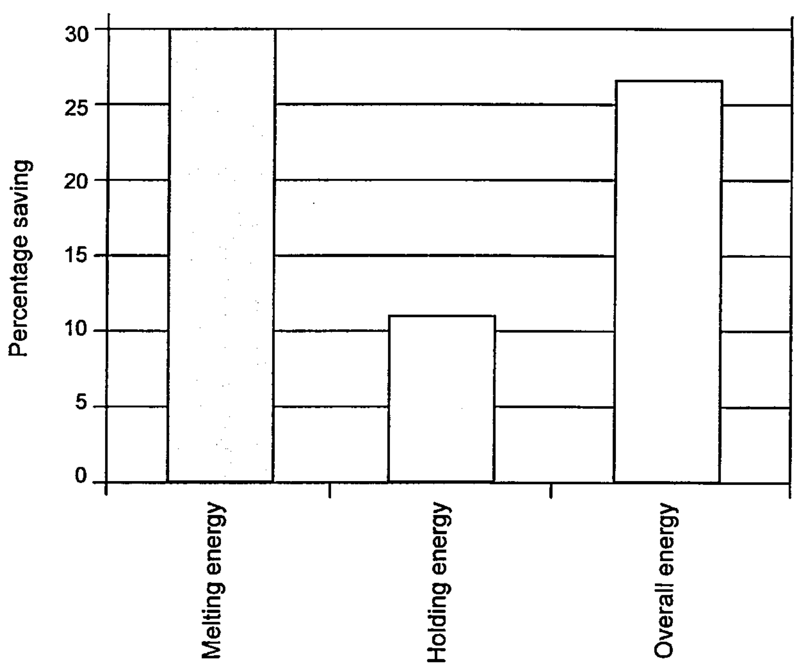


Figure 4.12. ***Potential energy savings in Foundry A.***

As shown in Figure 4.12, by implementing the measures discussed earlier, the potential energy saving for melting and holding in Foundry A could be as much as 26%.

4.3.2 Measures/Savings Summary – Foundry B

Foundry B purchased 4.9 GWh (12.7 GWh_p) of electricity and 13.7 GWh of gas in 2000, and despatched 970 tonnes of castings. Therefore, the overall SEC of the site was 27,216 kWh_p – equivalent to 98 GJ_p $tonne^{-1}$. For sand casting, ETSU (1997) reported 30 GJ_p to 130 GJ_p $tonne^{-1}$. In addition to metal melting and holding, Foundry B uses electricity to drive pumps, compressors, fans, fume extractors, machinery, and lighting. Apart from melting, natural gas is used for ladle heating, heat-treatment, thermal sand reclamation, space and water heating.

From the case study it was found that 2547 kWh_p are used to melt and hold one tonne of aluminium. Mould yields ranged from 36% to 55%. On average 5269 kWh_p is used to produce one tonne of saleable aluminium castings. Assuming that the findings from the survey are typical for the site, only 19% of primary energy is used for melting and holding metal prior to casting. This topic will be discussed in detail in Chapter 5.

(Foundry B is claiming an 80% discount of the climate change levy under the cast metal sector's negotiated energy agreement. Based on 2000 energy prices, the levy will add 5% to Foundry B's gas bills and electricity costs will rise by 2.6%).

Potential energy saving

A test was made to demonstrate the energy savings that could be achieved if covers were put on the furnaces when access to the melt is not required. At the end of the Friday afternoon shift, a temporary cover consisting of a disc of steel mesh sandwiched between two layers of 25 mm thick ceramic fibre blanket was placed on the 72 kW holding furnace. The melt temperature was allowed to stabilize at 780°C so that the furnace was in a steady state before the test started. 157 kWh were used during 16 hours 20 minutes, indicating a standing loss of 9.6 kWh h^{-1} – compared to 19.8 kWh h^{-1} from the uncovered furnace. This is a saving of 10.2 kWh h^{-1}.

The following list summarizes the measures and savings applicable to Foundry B:

1. The electric holding furnaces are kept fully charged at temperature from the end of the Friday shift until the start of the Sunday evening shift (53 hours). Using simple covers on the holding furnaces would reduce standing losses by 1081kWh per week, saving 13% of weekly energy used for holding.

2. Unless there are operational reasons for not doing so, during the weekend break the temperature of the metal could be lowered to 700°C (or perhaps lower). With covers on the furnaces, standing losses would be reduced by a further 1.6 kWh h^{-1} for each furnace, lowering the total losses for two furnaces by 23.6 kWh h^{-1}. Using covers *and* lowering the temperature would save 1251 kWh h^{-1} during weekends – an overall saving of 15%.

3. The intermittent mode of operation means that for approximately 25% of each shift metal is not being taken from the holding furnaces. During this time, the furnaces could be covered to make further savings of 586 kWh per week.

The total energy used by the holding furnaces during the week of the survey would have been 8391 kWh without the temporary cover used during the test described earlier. Measures 1-3 would reduce energy use by 1667 kWh per week – 20% improvement for holding.

4. The melting furnaces are not equipped with covers. The heat energy lost from the top of open gas-fired melting furnaces is at least equal to that from the electric holding furnaces. Except during charging, skimming the melt and scraping the dross from the crucible wall, the melting furnaces could be closed. These activities do not take more than 20 minutes per charge, which is about 20% of the operating time. If covers were provided, and used for 80% of the time – the melting furnace losses would be reduced by 1856 kWh_p. At an energy conversion efficiency of 30%, the saving would be 6187 kWh_p – raising melting efficiency by 11%.

5. During the study, the average demand for molten metal was 280 kg h^{-1}, with a peak requirement of 307 kg h^{-1}. Although two melting furnaces will be needed to supply sufficient metal to meet projected future output (when energy efficiency will rise), there are periods when one melting furnace could cope with the current requirements. To do this, arrangements would have to be made to enable molten metal to be transferred from either of the melting furnaces to either of the holding furnaces. At times when one melting furnace could meet the demand of 300 kg h^{-1}, the energy efficiency of the furnace in use would rise because of higher utilization, and the energy used to hold the other furnace at temperature (76 kWh_p per hour) would be saved. At present production rates, this would lower the energy used for melting by 15%.

6. Clearly, the greatest energy saving for melting would be gained by using one furnace at times when demand permits. Even if one of the melting furnaces was not used for only one day a week, there is a potential saving of 1824 kWh_p or 2% of the total energy input.

7. Preheating pouring ladles would permit lower metal temperatures in the holding furnaces. Lowering the metal temperature by 20°C would reduce the heat content of the

metal by 5 kWh $tonne^{-1}$ (1%), and reduce the furnace losses by at least a similar amount. Although the saving would be partially offset by the energy needed for ladle preheating, the thermal mass of the ladles is small when compared to furnace heat losses and the higher heat content of aluminium at 780°C.

8. Furnace flue gas analyses showed that the combustion air to fuel ratio of the melting furnace burners could be improved to give fuel savings. But the dynamic gas pressure supply to the furnaces fluctuates depending upon site demand. There are periods when the pressure drops below 20 mbar – the level for which the system was set up. Under such conditions, burners fire with high excess air, lowering the energy efficiency. The furnace manufacturer recommends that on high fire, the O_2 content of the flue gases should be maintained between 2% and 3%, (10.6% to 10.0% CO_2). Under these conditions, about 40% to 45% of the heat will be lost via the flue gases. The irregular gas supply pressure in Foundry B causes the air/gas ratio to drift. At times, O_2 readings ranged from 5% to 10% causing flue gas losses to increase by up to 67%. To avoid this, the furnace gas supply pipework should be modified to avoid pressure drops during periods of peak site demand. Combustion conditions should be checked on a regular basis (at least twice yearly) and adjusted if necessary. These actions could raise the energy efficiency of the melting furnaces by as much as 18%.

Points 4-8 demonstrate that 25 to 30% of the energy used for melting could be saved.

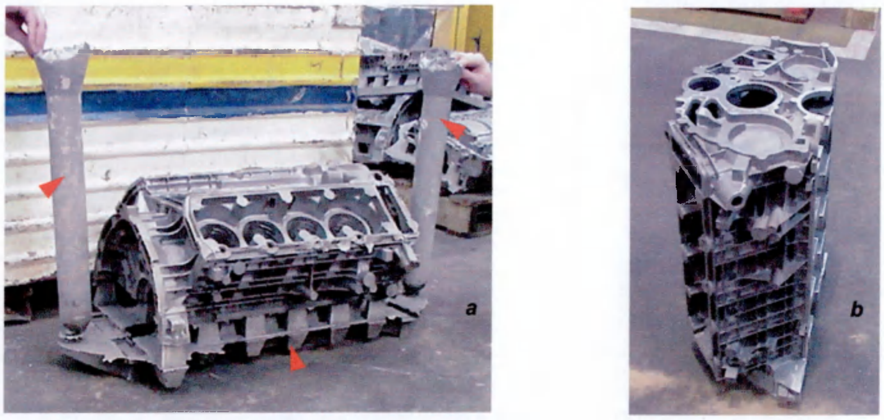


Figure 4.13. ***Typical casting from Foundry B's 'production' foundry, a) as cast (60 kg) b) trimmed (33kg).*** *(Arrows indicate the running system to be removed)*

9. Mould yield has a significant influence on the energy used for metal casting. For example, Foundry B makes a 60 kg casting (Fig. 4.13.b) from a mould with double pouring cups. (Fig. 4.9) Each cup has an internal diameter of 63 mm and is 500 mm long. The weight of metal in each cup is approximately 5 kg. If it were feasible to reduce the diameter of the pouring cup to 50 mm – without adversely affecting the casting quality – the poured weight would be reduced by approximately 4 kg. This would raise the mould yield from 55% to 59%, with an associated energy saving of 6.7%. There may be a secondary benefit from using smaller pouring cups. Oversize cups take more time to fill, which allows air to be taken down with the metal causing turbulence leading to oxides and entrained air which may lead to defects.

There may be sound reasons why it is not practicable to use smaller pouring cups; the hydrostatic pressure may be insufficient for effective mould filling, or the feeders may solidify too early. But in the interest of energy efficiency, the possibility should be investigated.

Foundry B savings summary

The energy savings identified for Foundry B are summarized here and in Figure 4.14.

Holding furnaces

Close covers during weekends	– 1081 kWh/week
Lower melt temperature at weekends	– 170 kWh/week
Close covers for 75% of operating time	– 586 kWh/week
Total reduction per week	– 1837 kWh
Total energy used per week	– 8391 kWh
Energy saving	**– 22%**

Melting furnaces

Use covers for 80% of operating time	– 6187 kWh/week
Monitor combustion conditions	– 5708 kWh/week
Total energy used per week	– 57 076 kWh
Energy saving	**– 21%**

Melting & holding system

Primary energy reduction	– {(1837 x 2.6) + 11 895} kWh_p
Primary energy used per week	– {(8391 x 2.6) + 57 076} kWh_p
Primary energy saving	**– 21%**

The energy saving measures outlined here, could reduce the total amount of energy used by Foundry B for melting and holding by more than 20%. (Fig. 4.14)

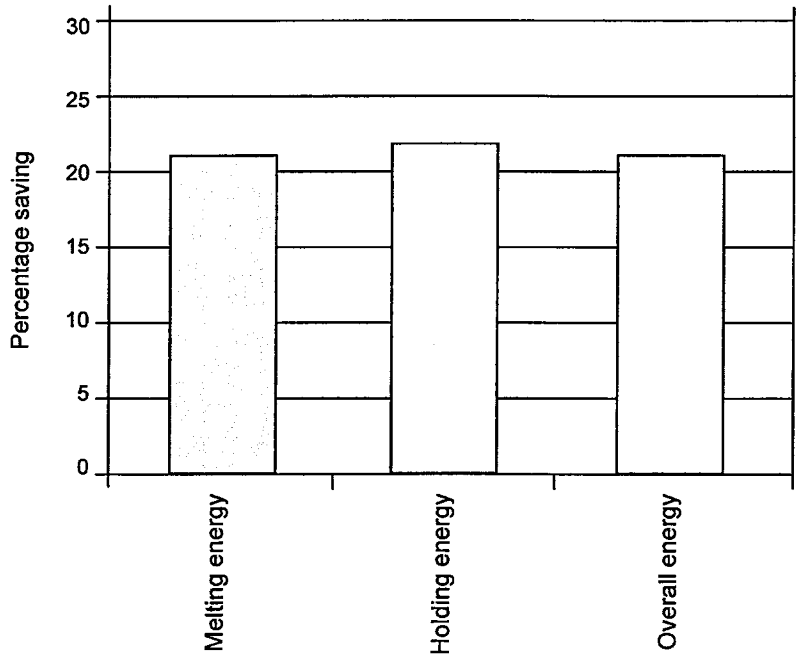


Figure 4.14. ***Potential energy savings in Foundry B.***

4.3.3 Measures/Savings Summary – Foundry C

Foundry C delivered 3818 tonnes of aluminium castings in 2000 of which 3600 tonnes were pressure diecastings. A further 97 tonnes of gravity diecastings were made by manual operation, and 121 tonnes in an automated cell that has dedicated gas-fired melting and electrical resistance holding furnaces.

Allowing for a metal loss of 5% and applying the energy inputs deduced from the survey, 9.7 GWh_p would have been used for melting and holding. During the year, the company purchased 11.5 GWh of gas and 27.9 GWh_p of electricity.

The overall SEC of Foundry C was 10 300 kWh_p $tonne^{-1}$, equivalent to 37 GJ_p $tonne^{-1}$. The ETSU 1997 SEC range for UK pressure diecasting foundries was 26 GJ_p to 52 GJ_p $tonne^{-1}$.

ETSU 2000 reported an industry average of 32 GJ_p $tonne^{-1}$. Metal melting and holding account for 25% of the company's site energy is use.

Potential energy saving – Pressure diecasting – Melting

Foundry C's gas-fired melting equipment and operating procedures are excellent. There is very little that could be done to improve the energy efficiency of the system at present. If demand increases, the efficiency should improve slightly as a result of higher throughput. It is planned to scrap the induction melting furnaces and replace the capacity with gas-fired equipment. This will reduce the use of electricity, lowering significantly the specific *primary* energy consumption and increase the utilization of existing melting furnaces which could improve their energy efficiency by at least 5%.

According to the supplier, the melting loss due to oxidation in the melting furnaces should be in the order of 1.0% to 1.2% (Paterson, 2001). The melting shop foreman claimed that the total metal loss from melting, treating and transporting in the molten state is approximately 2.5%. However, when this melting loss is compounded, the gross metal loss is actually double, i.e. 5%. Although the loss is within the usually accepted range for the type of furnace and melting processes involved, reducing the loss is the only possibility for energy saving in Foundry C's melting furnaces.

Potential energy saving – Pressure diecasting – Holding

The holding furnaces in Foundry C are all quite efficient when compared to the manufacturer's specifications. Although covers are closed during weekend breaks, it was noted that one third of the total energy is used during the weekend shutdown. The small difference between the average energy input when open during working periods and that when the covers are closed during the weekend is explained by the fact that the temperature of the liquid metal feed is usually higher than the control set-points of the holding furnaces. Heating is off for long periods after charging, until temperatures fall to the set band. The thermal inertia of the insulation and refractory crucibles, and slow thermocouple response cause wide temperature swings in the holding furnaces. This effect could be reduced by using three term (PID) self- and adaptive-tuning controllers to modulate the energy input more closely.

Although the holding furnace covers are usually closed for weekend breaks, they are not closed during die changing or other temporary stoppages. A small amount of energy could be saved if the furnaces were closed whenever diecasting machines are inoperative.

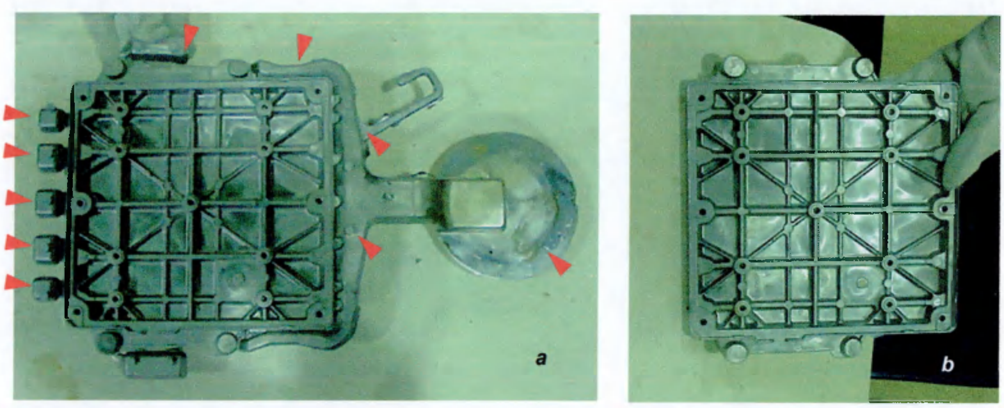


Figure 4.15. ***Casting from single impression die on Foundry C's 750 t machines a) as cast, b) trimmed.*** *(Arrows indicate the running system to be removed)*

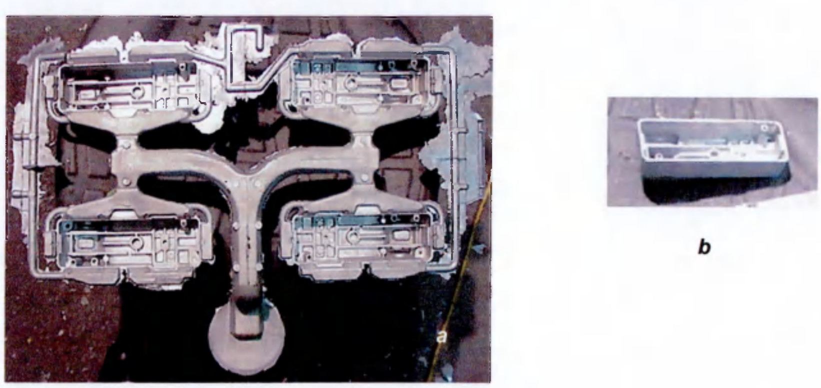


Figure 4.16. ***Casting from 4-impression die on Foundry C's 400 t machines a) as cast (2.49 kg) b) trimmed casting (4 x 0.20 kg).***

Casting processes were outside the scope of the energy study, but it was noted that some of the mould yields are quite low – ranging from 31% to 61%. Mould yield depends on several factors, but except for machine set-up parameters, yield is determined at the design stage of a casting and its tooling. It would be impractical to make yield improvements for existing products, but it is an area for future work to improve energy efficiency.

Some die runs were relatively short necessitating frequent tool changes that reduced machine utilization. Production scheduling usually depends on customers' demands. If the trend to shorter die runs persists, then techniques that shorten tooling change and set-up times should be adopted.

Potential energy saving – Gravity diecasting

The study shows that energy efficiency in the gravity foundry is very low. Some of the following measures would improve it:

1. Installing covers on the furnaces and using them whenever convenient, would reduce the standing losses from each furnace by 6 kWh h^{-1}. If covers were closed when the furnaces are melting, and during the half-hour shift break, based on single shift working the potential electricity saving on the four furnaces is 408 kWh per week – approximately 6% of the energy used at present.

2. Taking an average of 400 castings per shift as an example, the cycle time for each casting is one and a half minutes. Two thirds of this time is for solidification and extraction of the casting, and preparation of the die for the next pour. If operators could be encouraged to close furnace covers after pouring each shot, the cycle time would be unaffected, but the holding losses could be reduced by 36 kWh per cell per day. This would amount to 288 kWh per week or 4% of the present use.

Measures 1 and 2 demonstrate that the energy used for gravity diecasting could be reduced by as much as 18% simply by using covers on the furnaces.

3. Where possible, planning should avoid charging furnaces and holding liquid metal for non-productive periods.

4. The highest output from the two stations during a shift was 1217 kg – an average of approximately 130 kg h^{-1}. The alloys cast are either LM25 or a compatible AlSiMg alloy. It is therefore feasible to pre-melt in a single gas-fired furnace and transfer molten metal to the electric holding furnaces.

It is planned to re-locate the main melting facilities so that an existing small gas-fired tilting crucible furnace will be redundant. The furnace would be capable of melting up to 200 kg h^{-1} for a pouring temperature of 800°C. If melting is planned to match the production requirement, the gas required to melt in this furnace would be in the order of 1200 kWh $tonne^{-1}$ – including start-up and holding consumption, compared to 2500 kWh_p $tonne^{-1}$ with the present system using electricity to melt in the holding furnaces. (Table 4.13a)

Table 4.13a. ***Gas-fired melting furnace to supply two holding furnaces per station.***

		Day 1	Day 2	Day 3	Weekend	Day 4	Day 5	Total
Output	kg		735	255	0	1100	1377	3467 kg
Gas used	kWh		882	306	0	1320	1652	4160 kWh
SEC	kWh_p $tonne^{-1}$		1200	1200		1200	1200	1200 kWh_p $tonne^{-1}$

Table 4.13b. ***Station A – Energy used by two holding furnaces.***

		Day 1	Day 2	Day 3	Weekend	Day 4	Day 5	Total
Operating time*	hours		11.00	7.50	0	11.00	11.00	40.5 hours
Output - gross	kg		320	255	0	580	629	1784 kg
Output - net	kg		241	191	0	391	424	1247 kg
Mould yield	%		75	75		67	67	70 %
Energy input	kWh		253	173	0	253	253	932 kWh
Primary	kWh_p		658	449	0	658	658	2422 kWh_p

* Furnaces on.

Table 4.13c *Station B – Energy used by two holding furnaces.*

		Day 1	Day 2	Day 3	Weekend	Day 4	Day 5	Total
Operating time*	hours		11.00		0	11.00	11.00	33.0 hours
Output - gross	kg		413		0	520	588	1681 kg
Output - net	kg		328		0	414	468	1210 kg
Mould yield	%		79			80	80	72 %
Energy input	kWh		253	0	0	253	253	759 kWh
Primary	kWh_p		658	0	0	658	658	1973 kWh_p
Transferred to Auto Cell	kg					160		

* Furnaces on.

Operating the electric furnaces for holding only would use 1268 kWh_p $tonne^{-1}$ cast (1798 kWh_p $tonne^{-1}$ trimmed). Adding 1200 kWh_p $tonne^{-1}$ for melting in the gas-fired furnace gives an SEC of 2468 kWh_p $tonne^{-1}$ of castings, 2998 kWh_p $tonne^{-1}$ in the trimmed condition.

The changes outlined here would reduce the primary energy used for melting and holding in the gravity section from 3906 kWh_p $tonne^{-1}$ to 2468 kWh_p $tonne^{-1}$ of poured castings. This represents a primary energy saving of 37%.

(Calculations based on Foundry C's energy prices show that the present method of melting and holding in electric furnaces in the gravity section, costs approximately £89 $tonne^{-1}$ (trimmed). Using a gas-fired tilting furnace for melting, and holding in pairs of electric bale-out furnaces at each station, could reduce the cost to £35 $tonne^{-1}$).

Foundry C savings summary

Summarising, in the short term there is only limited scope for efficiency improvement in Foundry C's pressure diecasting operation. (Fig. 4.17) Reducing metal losses in the melting furnaces, using covers more on holding furnaces, decommissioning the induction furnaces and raising the utilization level of the two tonne per hour gas-fired melter would together save around 9% of the current energy use.

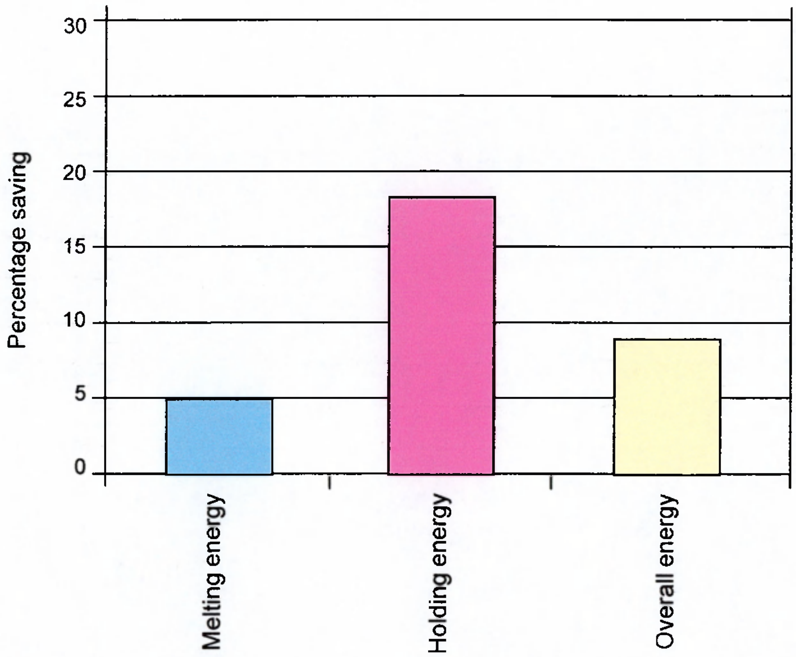


Figure 4.17. ***Potential energy savings in Foundry C – Pressure diecasting.***

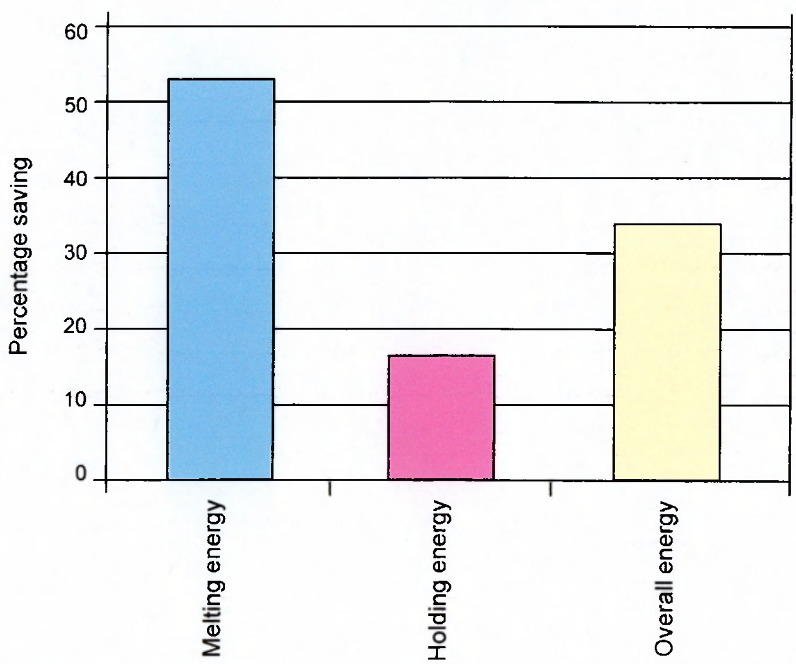


Figure 4.18. ***Potential energy savings in Foundry C – Gravity diecasting.***

However, between 30 and 40 per cent of the energy used for manual gravity diecasting could be saved. (Fig. 4.18) Assuming a nominal 10% improvement could be made in the automated gravity section and applying Foundry C's casting process mix – it is estimated that the primary energy used for melting and holding could be reduces by13% as illustrated in Figure 4.19.

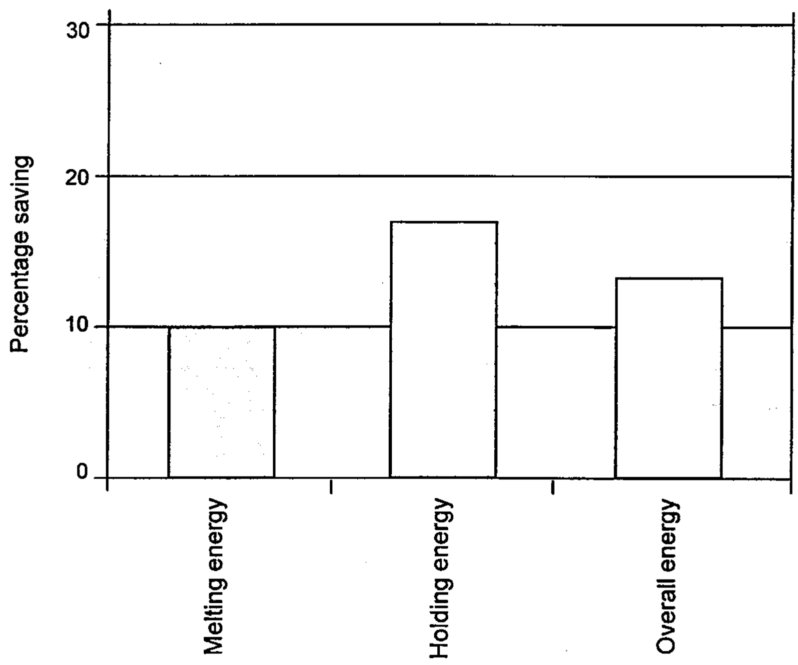


Figure 4.19. ***Potential energy savings in Foundry C.***

4.3 Effects of measures – Changes in SEC

Energy saving in foundries is sometimes possible by changing working shift arrangements and reducing the number of furnaces in operation. Furnaces in use then can be operated for longer periods and nearer to their optimum output. Changing working practices and operating less shifts of longer duration, or working extra shifts, improves plant utilization and minimizes the effects of process variables caused by production breaks. In process plants, particularly high energy consuming ones using furnaces that run continuously, the overall energy efficiency improves by eliminating the energy expended to maintain furnaces at temperature between shifts.

Better 'metal management' can significantly improve energy efficiency. Many aluminium foundries only cast metal for seven or eight hours per day; but furnaces may run either continuously, or are started up three or four hours before the beginning of the working shift. In the case of short shut-down periods, overnight for example, theoretically there is little difference between the two practices in terms of energy usage – both entail making up for the heat losses incurred during the non-productive period. Procedures usually depend upon other factors such as the economic advantage of holding surplus liquid metal at temperature rather than waste the energy stored in it by casting it into ingots to be re-melted later. This practice is impractical for some alloys, the metallurgical quality of which may be impaired when held in the molten state for long periods.

Demand level significantly influences the overall energy efficiencies of casting processes. If output falls, the SEC rises, particularly in diecasting foundries where shorter die runs necessitate more frequent tool changes during which furnace standing losses are incurred.

Specific energy saving measures – Foundry A

Melting furnace:

- improve temperature control;
- change operating procedures;
- modify the furnace exhaust;
- use one furnace to supply molten metal to more than one cell;
- replace defective insulation;
- adjust the fuel/air ratio;
- check combustion conditions regularly.

Holding furnaces:

- improve temperature control;
- replace defective heating elements;
- replace defective insulation;
- install covers and use whenever access to the crucible is not required;
- clean crucible walls more frequently to improve conductivity.

Improve die yields:

- tooling for new products should be designed to optimize yield and where possible reduce pouring temperatures without compromising mould filling and feeding during solidification. This may also raise productivity by reducing cycle times.

Specific energy saving measures – Foundry B

There is scope for improving the energy efficiency in Foundry B. The greatest improvements could be made by:

- better melting management (operational);
- metal management (planning);
- raising mould yields (design);
- use one furnace to supply molten metal to more than one holding furnace;
- replace defective insulation;
- adjust the fuel/air ratio;
- check combustion conditions regularly;
- install covers and use whenever access to the crucible is not required;
- clean crucible walls more frequently to improve conductivity.

Specific Measures – Foundry C

The scope for improving energy efficiency in Foundry C is limited to the following actions in the pressure diecasting foundries:

- reducing metal loss in the bulk melting furnaces;
- closing the holding furnace covers during die changing and other temporary stoppages;

and in the gravity foundry:

- install furnace covers;
- avoid holding liquid metal during non-productive periods;
- use gas for melting;
- investigate the feasibility of using one holding furnace per station.

Summary

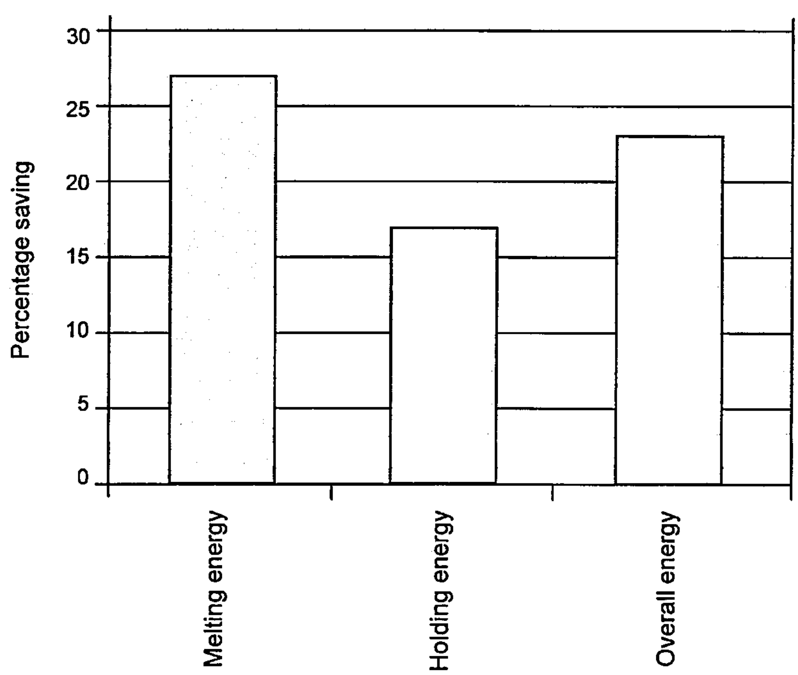


Figure 4.20. ***Average energy saving potentials for host foundries.***

Data gathered from the case studies is collated in Figure 4.20 and shows that the average overall energy saving potentials for melting and holding in the host foundries could be more than 20%. It would be reasonable to assume that savings of this order could be achieved by the aluminium casting sector as a whole. This proposition is discussed in Section 4.5.3.

4.4 Results of modelling

The host sites were used for the experiments to test the spreadsheet model described in Chapter 3. The costs of energy reduction measures estimated from the case studies for the lifetime of the scheme are shown in Appendix III. Several iterations were made before achieving the objective of a design for incremental levies applied to gas and electricity that would meet the following criteria:

- At least achieve the government's target for the sector of 11% reduction by 2010.
- No increase in site energy costs which include levies and efficiency improvement measures.
- Must be achievable with no-cost or low-cost measures.
- Efficiency improvement measures must have a payback of two years of less.

The proposed scheme is outlined here before presenting the outcome of experiments. The detail and the merits of an alternative levy scheme will be discussed in Chapter 5.

4.4.1 Analysis of experiments applied to case study sites (Appendix V)

Postulation 1 uses the existing levy rates and employers' National Insurance rates reduced by 0.3%. Foundry A pays the levies in full – for Foundry B and Foundry C levies are discounted by 80%.

To mitigate levy costs and energy improvement measures, Foundry A must reduce its primary energy use by 12% by 2010. The cost of reduction measures will be 0.3% of the total energy costs. Over the period the company will pay £357,133 in levies which is 12% of gas and electricity costs. If no action is taken, the levies will add 14% to the site energy cost.

Foundry B will have to reduce its primary energy use by only 3% to mitigate the costs of its reduction measures and discounted levy rates. The cost of reduction measures would be 1.4% of the total energy costs. Levies would be 3% of the costs of gas and electricity However, Foundry B has signed up to Target 2010 whereby it commits to reducing energy use by 11% otherwise it will forfeit the levy discount which will amount to £285,820 over the period. The threat of forfeiture is the incentive to meet the reduction target.

Foundry C's primary energy use must fall by 4% to mitigate the costs of reduction measures and discounted levies. Reduction costs represent 2% of the site energy costs under this scenario and levy charges would be 3% of energy bills. Foundry C has committed to an 11% reduction in energy use under the sector's Target 2010 agreement saving £435,710 as levy discounts over the lifetime of the agreement. This would be repayable if the sector fails to meet its 11% reduction target.

The case studies show that Foundry A can achieve the 12% reduction by implementing the measures discussed earlier. Foundry B should be able to meet its 11% reduction target with some nominal costs. But it will be difficult for Foundry C to meet the 11% reduction without some significant investments that may impair the economic viability of the site so that business could be lost or work transferred to other sites. In either case jobs would be lost.

Postulation 2 offers an alternative based on incremental levy rates applied in four phases. As for Postulation 1, the criteria set out earlier are to be met, namely, - site energy costs, including levies and no-cost or low-cost efficiency improvement measures do not increase, efficiency improvement measures have a payback of two years or less, and at least the sector's 11% reduction target must be achieved by each site. There are no reductions in employer's NI payments and the costs of reduction measures are the same as used in Postulation 1 but without the fees for target 2010 and audits for Foundry B and Foundry C. (Appendix III)

Phase 1 of the scheme is an introductory period of one year with nominal levy rates similar to the existing discounted rates. For the next year, Phase 2, levies are doubled. Phase 3 lasts three years with higher levy rates and the final Phase 4 uses the current rates.

Without increasing the pre-climate change levy energy costs incurred in 2000, Foundry A would reduce its energy use by 14%. Levies would represent 9% of energy purchases and reduction costs would be approximately 2% of the gross energy cost.

If Foundry B incurs similar costs for reduction measures to those applied in Postulation 1, it would be able to reduce energy demand by 15% with no overall cost increase. Levy charges would be 10% of billed energy costs. Energy reduction measures would be 3% of the total site energy cost.

Applying the scenario for Postulation 2, Foundry C could make 11% energy savings without increasing its total energy costs, including levies and costs of reduction measures which would be approximately 3% of the total.

Postulation 2 with incrementally applied levies meets the set criteria without imposing excessive economic or practical burdens on the three sites. Even if Foundry C fails to achieve the reduction of 11%, the impacts of the levies would not be crucial to the company's price competitiveness.

4.5 Summary of findings

4.5.1 Analysis of surveys – the existing situation

ETSU (1999), claimed that the specific energy consumption of Britain's non-ferrous foundry industry had fallen in recent years largely due to increased use of energy efficient melting and holding furnaces, and higher foundry yields. According to ETSU, the reclassification of non-ferrous foundries has probably exaggerated the apparent improvement in SEC in the period 1993-97 by several per cent. (The change in industry sector classification in 1992 moved the castings industries from Mechanical Engineering to Basic Metals. In terms of DUKES (Digest of UK Energy Statistics) categories this meant that *ferrous foundries* moved to Iron and Steel and *non-ferrous foundries* to Non-ferrous Metals)
The ETSU work (1993 &1997) referred to earlier, does not link the findings to the different levels of output that prevailed during the periods covered by the reports. Although the reduction in SEC was claimed as a success, if allowances had been made for the higher efficiency of plant when operated nearer to its designed capacity, as it was during the period covered by the second report, it may be that the improvement resulted from higher utilization, rather than fundamental energy efficiency improvement.

Another factor that influenced the findings was the more common use of electric coreless induction melting furnaces by larger aluminium foundries in the 1980s and early 1990s.

The operational energy efficiency of these furnaces was high since they were used to 'melt on demand'. As gas prices fell to an all-time low in 1996, many induction furnaces were replaced with gas-fired melting equipments. At the time, energy *cost* saving was the main justification for the change, rather than the energy efficiency. The economic benefits far outweighed the other advantages of induction melting. Even after applying the primary energy equivalent conversion factor for electricity, in many cases the SEC per tonne of metal melted by induction may have been lower than some of the less efficient gas-fired melting furnaces that subsequently replaced them.

Like all potential cost savings, energy cost savings, when taken in isolation may appear to be attractive. However, when such savings are related to the capital investment, commitment of resources and the total manufacturing cost of aluminium castings, the savings can be quite insignificant or unjustifiable against a background of low industrial gas prices.

If energy prices increase and output falls, the efficiency of energy use by the industry could fall to previous levels. The gain from improved energy efficiency then may equal the fall of efficiency due to lower plant utilization. If a high output with high energy price scenario prevails - the energy efficiency of the industry would be high – but the converse could be disastrous in terms of CO_2 emissions.

The questionnaire revealed that the principal sources of energy waste in aluminium foundries were from inefficient furnace operation, melting loss and low mould yield. Scrap is an emotive subject and is rarely revealed even if it is actually measured in foundries – but it is likely that scrap is a major contributor to low energy efficiency. ETSU (1994) claimed that at least 10% of all castings made are scrapped either in the foundry (internal rejects) or rejected by customers (external rejects). It is possible that quality management would have improved scrap rates since then, but quality control in many foundries often means sorting for defective castings rather than reducing the number produced.

The consensus of opinion gathered from the interviews was that much needed to be done to increase awareness of wider environmental externalities in general and the need to improve energy efficiency in particular. Some form of government financial assistance was seen to be the best way to encourage energy improvement but economic penalties should be borne only by those that disregard the call.

4.5.2 Practices & housekeeping

Foundry A – Gravity diecasting

The gas-fired furnace used 2817 kWh $tonne^{-1}$ of aluminium melted. Holding in a pair of electric resistance furnaces used 3355 kWh_p $tonne^{-1}$ of trimmed castings produced. The overall energy use in the cell was 10 431 kWh_p (38 GJ_p) $tonne^{-1}$ of trimmed castings.

In 2000, the overall site SEC for Foundry A was 95 GJ_p $tonne^{-1}$, compared to the ETSU (1997) range of 23 GJ_p to 45 GJ_p $tonne^{-1}$ and 37 GJ_p (ETSU 2000). The reasons for the wide deviation between Foundry A's SEC and the ETSU average have been discussed.

Foundry B – Sand casting

The average energy for melting in gas-fired crucible furnaces was 1794 kWh $tonne^{-1}$. Holding in a pair of electric resistance furnaces used an average of 1479 kWh_p $tonne^{-1}$ of cast metal. The energy input to the cell was 5269 kWh_p (19 GJ_p) $tonne^{-1}$ of trimmed castings.

The site SEC of Foundry B for 2000 was 27 MWh_p $tonne^{-1}$ or 98 GJ_p, which lies towards the upper end of the ETSU range of 30 GJ_p to 130 GJ_p $tonne^{-1}$, and 76 GJ_p (ETSU, 2000). The high quality demanded for Foundry B's castings gives rise to high reject levels; this, coupled with the relatively low mould yields (for sand casting), and the large amount of energy used for thermal sand reclamation, explains why the SEC is higher than the normal average for sand foundries.

Foundry C - Pressure diecasting

The pair of gas-fired 'tower' furnaces used 792 kWh $tonne^{-1}$ melted. Holding in resistance furnaces at the pressure diecasting machines used an average of 790 kWh_p $tonne^{-1}$ of trimmed castings. Holding in a gas-fired crucible furnace at the pressure diecasting machine used 751 kWh $tonne^{-1}$ of trimmed castings. The average energy used for holding (gas and electric) was 768 kWh $tonne^{-1}$ of trimmed castings. The energy consumption for melting *and* holding for pressure diecasting was 2316 kWh_p (8.3 GJ_p) $tonne^{-1}$.

Foundry C - Gravity diecasting

The average energy used for melting and holding in pairs of electric resistance crucible furnaces in the gravity diecasting section was 5801 kWh_p (21 GJ_p) $tonne^{-1}$ of trimmed castings.

The overall SEC for Foundry C was 37 GJ_p $tonne^{-1}$, compared to the ETSU range of 26 GJ_p to 52 GJ_p $tonne^{-1}$. ETSU's revized average for pressure diecasting foundries is 32 GJ_p $tonne^{-1}$.

Energy use in foundries

Energy Consumption Guide 38 (ETSU, 1997) claimed that ETSU activities had met their objectives to reduce the energy consumption in non-ferrous casting production. However, although there had been energy improvements during the four year period covered by the work, it was considered that there was plenty of scope for further savings.

According to ETSU, the main opportunities for energy savings in foundries were:

- melting and holding, where energy is likely to be of increasing importance as energy costs, particularly for gas, have been rising since their lowest point in 1996;
- improving mould yield, which simultaneously reduces energy and other operating costs, increases the effective capacity of plant and helps to reduce non-recoverable metal loss.

Although there were cases where efficiency improvements were attributable to changes to more efficient furnaces and better practices, in the time-frame of the survey, aluminium casting output rose by 25%. It would be expected that during a phase of business growth, some of the improvement would have resulted from increased productivity and the concomitant higher efficiency from better plant utilization. It can be argued this factor alone would have created much of the improvement. ETSU (1999) later alluded to this, and referred to its effect on the recorded SECs for many industrial sectors at the beginning of the 1990s.

ETSU (1997), reported that on average, approximately 42.6 GJ_p (11,833 kWh_p) of energy were used to produce one tonne of aluminium castings. The figure includes all site energy use including heat-treatment and machining when done in-house. In pressure diecasting foundries, the energy used per tonne ranged from 26 GJ_p to 52 GJ_p. The energy use for sand casting was 30 GJp to 130 GJp per tonne and for gravity diecasting – 23 GJ_p to 45 GJ_p. The lower range figures are probably from foundries that supply in the as-cast condition without machining and heat-treatment.

ETSU (2000) updated the primary energy consumption averages of the three main aluminium casting routes to 76 GJ_p for sand, 32 GJ_p for pressure die, and 37 GJ_p for gravity die. As shown in Table 4.14, all of the host foundries fall above the averages. The deviations may be because Foundry A and Foundry C supply a large proportion of castings in the fully machined condition, and Foundry B uses on-site heat-treatment and thermal sand reclamation plants.

Table 4.14. ***SECs of host foundries compared to ETSU figures.***

Casting process	Host Foundries GJ_p tonne^{-1} sold	ETSU (1997) Range GJ_p tonne^{-1} sold	ETSU (1997) Mean GJ_p tonne^{-1} sold	ETSU (2000) Average GJ_p tonne^{-1} sold
Sand (B)	98	30 – 130	80	76
Gravity (A)	40	23 – 45	34	37
Gravity (C)	39			
High pressure (C)	37	26 – 52	39	32
Average (all processes)	47	25 – 55		39

Letters in parenthesis refer to the nomenclature used for host foundries

Since the ETSU energy data includes all energy uses for producing 'saleable castings' it is not possible to make direct comparisons with all of this work. It is unrealistic to compare the overall energy performances of aluminium foundries, even between those using the same casting route. Discrepancies are caused by the different conditions of despatched castings, – trimmed, part machined, finish machined, or heat-treated. These 'downstream' processes all require significant amounts of energy. It would be feasible to measure the SEC for different casting conditions by monitoring each sub-process. However, this would require metering energy inputs to sub-processes – something that is lacking in most foundries.

Except for the two large melting furnaces in Foundry C, the host foundries for the case studies did not have means for measuring energy inputs at the point of use. To implement energy management systems, foundries will have to install sub-metering – preferably on each item of plant.

It may not be practical to impose minimum standards for process performance on energy intensive industries, nor feasible to impose minimum efficiency standards on large process equipment. However, for the future it could be mandatory for all new process plant above a pre-determined energy rating to have energy monitoring devices as original supply.

4.5.2 Effects of measures: Review of case studies

The principal aim of the case studies was to measure under normal operating conditions, energy used for the various aluminium casting processes. A secondary aim was to find the specific energy consumption for the entire production process on each site. Although it is not feasible to make direct comparisons for this, since foundries deliver castings to customers in varying conditions, comparisons may be made between different melting and holding systems, and due allowances can be made for varying metal temperatures and other factors that influence energy use.

Gravity diecasting

The data from Foundry A gave an SEC of 4153 kWh_p $tonne^{-1}$ of metal cast using gas for melting and electricity for holding. By comparison, the gravity section of Foundry C used

3906 kWh_p $tonne^{-1}$. In terms of primary energy and the associated emissions, there is little difference. Both systems could be improved as discussed earlier, Foundry A could improve its energy efficiency by:

a) using smaller melting furnaces;

b) modifying existing furnaces (Chapter 4, Para. 4.3); or

c) raising the utilization factor of existing furnaces by supplying molten metal to more than one cell from less furnaces; and

d) using covers on the electric holding furnaces.

Logistically, option 'b' would be the most feasible option for Foundry A. Modifying the furnace to rear exhaust would lower the melting energy to 1972 kWh $tonne^{-1}$ – a 30% saving. Option 'd' could save 11% of the holding energy, lowering the as-cast figure to 3161 kWh_p $tonne^{-1}$ (as cast). This would be an overall improvement of 24%.

Changing the melting and holding system in the gravity section of Foundry C could lower the energy use to 1992 kWh_p $tonne^{-1}$. (Tables 4.13a – 4.13c). This would be 37% lower than present and may be typical for many smaller gravity diecasting foundries.

Sand casting

Foundry B uses 2507 kWh_p $tonne^{-1}$ of poured metal. If the changes proposed earlier were implemented, this could be reduced to 2095 kWh_p $tonne^{-1}$ – 16% energy saving. Foundry B is a relatively large aluminium sand casting foundry – smaller foundries without the benefits of scale may be less energy efficient but may have similar energy saving potential.

Pressure diecasting

The annual production of Foundry C is more than three times greater than Foundries A and B. The higher throughput justifies the use of larger more efficient central melting furnaces. Pouring and casting temperatures are low. These two factors alone have a marked influence on the SEC of high-pressure diecasting compared with sand and gravity diecasting. The study showed that the energy used for melting to be 1192 $kWh_p\ tonne^{-1}$ cast, compared to 3273 $kWh_p\ tonne^{-1}$ for sand and 6172 $kWh_p\ tonne^{-1}$ for gravity diecasting.

4.5.3 Contributions – Discussion and summary

From the studies, except for pressure diecasting in Foundry C, the findings confirm that there is plenty of scope to improve the energy efficiency of aluminium casting. From the case studies data, Table 4.15 shows that in sand and gravity foundries there could be energy savings of 16% and 23% respectively for melting and holding.

Table 4.15. ***Breakdown of primary energy use for melting & holding in host foundries with BAU potential savings by process.***

Process	Melting & holding $GJ_p\ tonne^{-1}$	Melting & holding $GJ_p\ tonne^{-1}$ - BAU	Potential Reduction %	Annual output tonnes	Energy Used GJ_p	Potential Saving GJ_p
Sand (B)	19	16	16	970	18 430	2451
Gravity (A)	22	17	23	1083	23 826	4184
Gravity (C)	21	13	38	218	4578	1080
High pressure (C)	8	8	5	3600	28 800	1440
Average (all processes)			**12**	**5871**	**75 634**	**9154**

Letters in parenthesis refer to host foundries nomenclature

Although the potential for improvement in Foundry C's gravity section seems very high, it is achievable – without major capital investment. Furthermore, it is likely many of the small and medium sized UK aluminium foundries would have similar SECs to those in

Foundries A and B. Even if financial constraints rule out major changes such as those proposed for Foundry C, changing working practices, and better furnace and metal management could reduce the energy used by for melting and holding by 20 to 30%.

Table 4.16. ***Proportion of site energy used for melting & holding in host foundries.***

Process	Output per annum	GJ_p tonne^{-1} sold	Site energy (GJ_p)	GJ_p tonne^{-1} (Trimmed)	Melting & holding (GJ_p)	Proportion of site energy (%)
Sand (B)	970	98	95 060	19	18 430	19
Gravity (A)	1083	40	102 600	22	23 826	23
Gravity (C)	218	39	8502	21	4578	54
High pressure (C)	3600	36	129 600	8	28 800	22
Total	**5871**		**335 762**		**75 634**	**23**

Letters in parenthesis refer to host foundries' nomenclature

ETSU's ranges of energy use by aluminium foundries include all uses whereas this work is concerned mainly with the energy used for the production of 'raw' castings. For discussion purposes, Table 4.16 shows the proportions of energy used by the host foundries as a percentage of the total site energy use. Explanations for the widely varying figures were given earlier.

The 1997 census of the UK foundry industry (DTI, 1998) indicated that there were around 200 aluminium foundries. Since that time there have been several closures, and some downsizing and re-structuring of larger foundries. There have been a number of start-ups and expansions of smaller foundries during the intervening time. On balance, the total number of sites and output are probably unchanged. Assuming no growth since 1997, the output of aluminium castings from UK foundries is approximately 200,000 tonnes per annum. According to the report, the breakdown of output of aluminium castings by manufacturing process is 8% sand, 54% gravity, 5% low pressure, and 33% high pressure. The balance of 1% was made up of other processes such as 'lost foam' and investment casting. The figures are based on the actual mix declared by the respondents to the DTI census questionnaire and are claimed by the authors to be statistically representative of the sector as a whole.

For the extrapolation that follows, melting and holding energy for low-pressure diecasting has been taken as similar to that for gravity diecasting. Usually, a melting régime similar to that described at Foundry A – liquid metal being transferred from gas-fired melting furnaces to electric holding furnaces integral with the diecasting machines. Mould yields for low-pressure diecasting are usually in the order of 80%; this has been allowed for by adjusting the energy needed to produce one tonne of trimmed castings.

Table 4.17. ***Annual energy use and projected saving for melting by aluminium casting sector.***

Process	Percentage of total*	Annual tonnage	GJ_p $tonne^{-1}$	TJ_p $annum^{-1}$	ACE reduction %	Saving TJ_p $annum^{-1}$
Gravity**	54	108 000	22	2376	17	404
Low pressure	5	10 000	19	190	17	32
Sand	8	16 000	19	304	16	49
High pressure	33	66 000	8	528	5	26
Total	**100**	**200 000***		**3398**	**15**	**511**

* 1998 Census of the UK Foundry Industry. (DTI, 1998)

** Based on Foundry A data

The SECs for each casting process and the reductions postulated from the case study data are shown in Table 4.17. The performance data have been applied to the UK aluminium foundry sector using the breakdown by tonnage from the DTI census. It can be seen that applying the BAU measures proposed in the analyses of the surveys could save 15% of the energy used for melting and holding metal in the liquid state. These are no-cost or low-cost changes that could be applied throughout the sector as the first level of reducing SEC.

The second level of measures should be the improvement of metal management by lowering metal temperatures when possible and scheduling melting operations to match production requirements. This could save at least 5% of the energy used at no cost to the industry.

ETSU (1994) claimed that at least 10% of all castings made are scrapped in the foundry or rejected by customers. Later ETSU studies (1996) revealed that internal scrap figures varied considerably from 1.5% to 24%. ETSU (1997) reported that the non-ferrous foundry industry's scrap and reject levels fell from approximately 8.5% to 6.5% between 1992 and 1996. If this could be reduced further to 5%, it would improve productivity by 1.5% with the accompanying energy saving. Reducing scrap would make a significant contribution to energy saving by the sector.

Improved furnace control and management could reduce irredeemable metal loss by oxidation when in the molten state. The compounded loss is double the specific loss for a 50% mould yield. For example, when a tonne of metal is melted, if 5% is lost by oxidation, 950 kilogrammes is available for casting, of which only 475 kg is 'saleable', the remainder is re-melted when 5% of *that* is lost also. After only 10 cycles, the overall loss is almost 10%. Not only does this represent an economic loss of an asset – it also wastes energy in the process, and the embodied energy from the metal's original conversion from bauxite. It is not unreasonable to suggest that there is the potential for reducing melting loss by one percentage point to 4%. This would reduce the energy needed by 2% for an average mould yield of 50%.

4.6 Summary

The information gathered from the studies undertaken in the three host foundries is similar to ETSU's estimates, demonstrating that there is potential for significant energy saving for metal melting and holding in aluminium foundries, without incurring significant costs.

Extrapolation of the results of the practical study in section 4.5 indicates that 20% improvement in melting efficiency is feasible. Studies by DETR (1998a) show that organisations waste typically around 20% of their energy. ETSU estimates that 10% of the energy used for site services other than melting and holding could be saved by better 'house-keeping' measures at no cost.

The practical work undertaken shows that the energy efficiency of metal melting and holding the aluminium casting sector could be improved by 19%. The improvement measures outlined earlier are modest and it is likely that the aggregated energy saving could be at least 20% without major capital investments – the 'BAU' scenario. Applying ETSU's estimate to non-melting processes of foundries, it can be argued that by improving 'whole-site' energy efficiency, there is ample scope for mitigating the effects of climate change levies without impairing competitiveness of UK aluminium foundries.

Table 4.17 shows that on average 23% of site energy is used for melting and holding in aluminium foundries. Improving melting and holding efficiency by 20% would reduce the sector's SEC by 5%. The balance of site energy use (77%) is for site services. This finding is agrees with the ETSU (1995) estimate that foundry services account for 77% of the primary energy used in UK foundries (all metals). ETSU claims that 10% of the energy used for site services could be saved by improving practices, monitoring and targeting (M&T), or by direct action. Using 77% as a basis, saving 10% of site services energy would reduce the sector's SEC by 7.7%, which would give an aggregate reduction for the sector of almost 13% with minimal investment.

DETR (1998a) estimates that organisations waste typically around *20%* of their energy. If this is so, then the energy used for foundry site services could be reduced 14.4%, which when added to the 5% reduction in melting and holding energy use, would lower the SEC for the aluminium casting sector by as much as 20%. This is close to the original 21% target set by ETSU for the foundry sector. (See Chapter 2, Section 2.7)

Chapter 5: Conclusions & Implications

5.1 Introduction

The secondary and primary research undertaken and reported in the previous chapters suggested that to meet the government's targets for reducing greenhouse gas emissions, strong measures to encourage energy efficiency in all sectors of the UK economy must be introduced as soon as possible. Strategies to achieve the reduction targets will differ to suit each sector of the economy. Compared to domestic or transport, business energy users may be seen as a relatively soft target for economic instruments introduced specifically to serve its greenhouse gas reduction policy.

Government policy and the problems created for industry by the existing climate change were discussed in Chapter 2. The findings from the case studies undertaken in the primary research reported in Chapter 4, indicated that there was scope for reducing the specific energy consumption of the aluminium casting sector. However, the existing climate change levy has created some anomalies.

Table 5.1. ***Economic effects of existing CCL scheme on host foundries.***

Company	Number of employees	Payroll (£ per annum)	NI saving (£ per annum)	CCL (£ per annum)	Net cost (£ per annum)
Foundry A	100	1,700,000	5,100	45,488	40,388
Foundry B	200	3,400,000	10,200	8,308	-1,892
Foundry C	200	3,000,000	9,000	12,671	3,671

It was demonstrated in Section 4.4.1, that Foundry A can only mitigate levy costs by reducing its energy consumption by 12.8%, otherwise the company's levy will cost nine times more than the reduction in NI payments. Foundry B, after 80% levy discount will receive 25% more in NI reduction than its levy charges but has the cost of energy efficiency measures and must meet its commitment to the 11% sectoral reduction target. Foundry C's position is the most difficult to mitigate; even after 80% levy discounts, its levy cost will be 35% more than NI reductions.

In order to find what effects the present levy scheme is having on a random selection of businesses outside the foundry sector, information was collected from a large metal part manufacturer (Site D), a first tier automotive supplier (Site E), an engineering goods distributor (Site F), an accountancy firm (Site G), and a small hotel (Site H). The costs of the existing climate change levies and NI reductions for each site are shown in Table 5.2.

Table 5.2. ***Economic effects of existing CCL scheme on Sites D to H .***

Company	Number of employees	Payroll (£ per annum)	NI saving (£ per annum)	CCL (£ per annum)	Net cost (£ per annum)
Site D	1000	27,000,000	81,000	41,659	-39,341
Site E	1500	22,500,000	67,500	18,000	-49,500
Site F	12	340,000	1,020	230	-790
Site G	85	1,700,000	5,100	514	-4,586
Site H	25	192,000	576	1,048	472

Site D is an IPPC site and qualifies for an 82% discount on the electricity levy and 80% on the gas levy, but is committed to a site specific energy reduction target of 8%. Unless Site D fails to meet its target, it will save twice as much in NI contributions as levies. The NI saving should cover the cost of Site D's energy management system but not the costs of reduction measures. To mitigate the impact of the discounted levy, the company has to reduce SEC by only 5%; but if it fails to meet the 8% reduction target, it will have to repay NI discounts that will amount to around £200,000 per year.

Site E is also covered by IPPC and has to achieve a site SEC reduction target of 11% in return for 80% levy discounts. It is not a very energy intensive business and has a relatively large workforce. Consequently, NI savings will be almost four times its discounted levy payments and should be sufficient to meet the costs of implementing energy saving measures.

From Table 5.2 it can be seen that two non-manufacturing firms have a financial gain without reducing energy use. Site F saves four times the CCL from reduced NI contributions. Site G's employment cost saving is ten times levy payments. Conversely, the relatively low wage rates in the catering industry mean that Site H's CCL charges are double the NI saving. To alleviate the imbalance, Site H will have to reduce energy use by 15% – this will be difficult without reducing the comfort levels expected by clients or major investments in energy conservation measures.

As predicted in Chapter 2, some non-manufacturing firms have large net gains without reducing energy consumption whereas energy dependant companies have either increased costs or the task of meeting set targets. This situation explains the findings of Thrower (2001) which showed that over 60% of businesses had not taken any new measures to improve energy efficiency. If this is so, the levy has not received the kind of response that is needed from the non-energy intensive sectors that have net financial gains from the existing scheme.

The effects of incremental levies on the case study firms were covered in Chapter 4. When the incremental levies are applied to the non-manufacturing sites and the NI reduction is removed, the situation changes. To mitigate the levy costs, Site F would reduce energy use by 14%, Site G by 15% and Site H by 11%. This is the level of response needed if the government is to meet its commitments. If however a risk of economic damage becomes apparent – an incremental scheme is flexible and can accommodate adjustments if necessary.

The government must aim to avoid damaging any one sector of business, but energy intensive industries are the most vulnerable to the cost impacts of energy levies and should be treated fairly. Furthermore, unlike the service sector, energy intensive industries are those most likely to be driven abroad to avoid levy costs.

To avoid the negative effects of the existing levy on energy intensive industries, an alternative is needed that would encourage companies to make the energy savings that the case studies indicate are possible and meet the government's targets without damaging competitiveness. To do this, an alternative model was developed and its effects on energy savings calculated. In this chapter the development and testing of the alternative model will be explained, and then an overall conclusion discussed.

5.2 Conclusions

There must be mechanisms for adjusting strategies to suit conditions that will inevitably change. The government's targets for the reduction of CO_2 emissions should have been in the past and should in the future be evaluated at the same time as the policies are created. If this is not done, there will be differences between the targets and the policy design. It must be possible to accommodate any differences as they manifest. If goals are set without sound bases for policy designs, there is a high risk of failure. There is also a strong chance that components of policy in isolation will result in only partial success; but by assessing the interactions between the components, possibilities for success improve.

At a company level, enterprises need to find a balance between environmental compatibility and economic feasibility. Economy is an essential basis for business *and* a sound ecology. It is imperative that UK business co-operates with the government in its ecological and economic objectives. There *is* a choice – but for the sake of future generations, it is unacceptable for business to behave irresponsibly.

5.2.1 An alternative strategy

If the UK is to have a thriving industrial sector in its economy *and* meet carbon emissions targets – the current levy scheme for business energy use may fail to meet the government's objectives. For many businesses, the economic benefit of reduced employers' national insurance contributions lower employment cost by much more than the cost of the CCL. This over-generous compensation may create employment in the service sector by lowering the cost of labour. However, any gain in employment could be at the expense of more energy intensive industries. Furthermore, the present system will be cumbersome to administer for both business and government departments.

Levy discounts for companies that qualify under the current negotiated energy agreements, will not necessarily reduce the overall cost to them. In return for the discount, not only do they have costs to reduce their specific energy consumption by an amount determined by outside agencies, they have the costs of installing and maintaining energy management systems, and implementing energy efficiency improvements.
Each sector included in the levy discount scheme through negotiated energy agreements has a total reduction target. The target is shared between participating companies according to their ability to improve energy efficiency. If a sector fails to achieve its target, individual companies included in the sector will be audited, and those that have failed to meet their

prescribed target will have to repay the discount. Repayment could create disastrous consequences for companies that are not financially sound.

The introduction of the climate change levy coincided with the new electricity trading arrangements (NETA) and other deregulatory rulings by OFGEM that lowered electricity prices. This means that the levy did not raise the cost of electricity for most businesses. On the other hand, contract gas prices rose so that the levy has become a less significant component of business gas costs. In some cases this situation may lead to switching some processes from gas to electricity – a change that could increase primary energy consumption and carbon emissions.

As the UK climate change levy is intended to raise companies' energy costs, they inevitably seek to recover as much of the increase as possible through cheaper supply contracts in the deregulated market. This will not lead to reducing the amount of energy used, but simply reduce the economic impacts of the levy.

The reduced employers' National Insurance (NI) contributions under the present CCL scheme nullifies the impact of the levy on many companies and gives a positive benefit to businesses with relatively low energy use. But the aggregated energy used by these companies is significant. It is important that these organisations must be encouraged to reduce their energy use by paying the levy in full *without* reduced NI payments.

An alternative incremental levy scheme, as presented here, would be more equitable for energy intensive industries, and should be investigated by policy makers. Government approved sectoral reduction targets can be determined for each business sector in a similar way to those for the NEAs. The target setting process should involve representation from each business sector – exactly in the way that the current sectoral discount scheme evolved to address the issues raised by those most vulnerable to the adverse financial impacts of the existing levy scheme. It would be practical to use current sectoral targets in the first phase of the proposed incremental scheme.

Research that has been undertaken in the area of energy efficiency can be divided into three main categories:

- determine the scope for CO_2 reductions from industrial processes;
- review strategies to address the problems; and
- propose ways to encourage energy efficiency improvement.

The work is valid, but no single approach is likely to satisfy completely the main objective of reducing business energy use, unless it addresses the specific needs of various business sectors and enterprise groups. This is extremely difficult since there are many criteria that characterize companies.

Enterprises are usually categorized by criteria such as size by output, by number employed, and sector classification. Clearly these characteristics are unique for each enterprise, which means that there cannot be a single initiative that could be applied to all with any certainty of success. Furthermore, for the climate change levy, the main distinction has been between energy intensive sectors and sites that are regulated by Integrated Pollution Prevention Control (IPPC). This has created anomalies that could lead to unfair financial burden for some companies or indeed whole sector.

There are weaknesses in the climate change levy as now applied – but it is a first step and there is time to address the deficiencies. To scrap the climate change levy in its entirety as suggested by some trade bodies and threatened by the parliamentary opposition, would be a poor response to the criticisms of the levy. To replace it only with grants and tax credits as proposed by critics of the scheme would encourage good behaviour but not punish bad behaviour sufficiently to be effective. The penalty of exclusion from financial rewards would be only marginal. To discard the CCL in its entirety and replace it with an emissions trading scheme would be unworkable in the short-term.

Marshall concluded that there was no viable alternative to some form of tax or levy linked to energy use. There are weaknesses in the present scheme, but there is time to review these and restructure the levy package to address them. It is not too late for the government to review the CCL along the lines proposed here. The amendments would simplify the system of applying the levy and distributing the revenue in more equitable ways to achieve the desired reductions in carbon related emissions. At least, the proposals would give time to design a new scheme to meet the objectives without compromising the competitiveness of UK business in *international* markets.

The Marshall Report called for a tax to be introduced at a low level and recommended that changes in the rates of tax should be made in a gradual and predictable way to maximize the incentive to invest in improved energy efficiency. It was proposed that the revenues should be recycled in full to business – for example through schemes promoting energy efficiency to avoid damage to competitiveness.

The introduction of incrementally rising levy rates as proposed here would give energy intensive sectors time to adapt to the government's energy reduction policy. This would satisfy the objectors, give the government feedback on the effectiveness of the levy, and allow time to develop an emissions trading system for larger energy users. An incrementally increasing levy would also allow business to prepare for subsequent phases and pre-empt possible impacts on operating costs.

In the long-term, a mix of economic measures, taxes and tax credits is likely to be most successful, since even in some energy intensive processes such as metal casting, the energy cost element is not very significant when seen as a proportion of the *total* manufacturing cost.

An alternative arrangement could be based on these simple changes to the exisitng scheme:

- apply incremental CCLs to all business sectors with no exemptions;
- do not reduce employers' NI contributions; (this would increase the incentive to reduce energy waste in non-energy intensive sectors);
- hypothecate revenue from each sector that qualified for energy intensive status and existing NEAs;
- redistribute the revenue in full, as grants and enhanced capital allowances against corporation tax for investments in energy efficient technologies.

A strategy based on the above, would encourage behavioural change and investment in new energy efficient technologies to reduce future carbon emissions. Those that respond to the CCL by reducing their SEC could gain from investment opportunities, new business and increased profit. It would strengthen the firms that respond, and increase their short term and long term competitiveness. The causal loop diagram (Figure 5.1) illustrates the proposition. Conversely, organisations that do not improve their energy efficiency will fail and their business will be taken up by more efficient competitors.

Recycling the CCL revenue as grants and tax breaks for energy efficiency measures would reduce energy use by firms that take advantage of the incentives. It would improve their competitiveness even though they would pay levies. Improved competitiveness would increase business which in turn will reduce SEC.

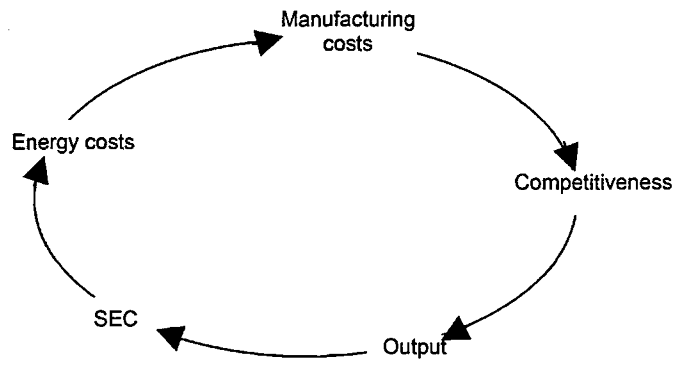


Figure 5.1. ***Manufacturing costs causal loop diagram.***

By raising the levy incrementally, the annual revenue would rise even though specific energy consumption should fall. Revenue would increase also with increasing industrial output. Increasing revenue would provide more funding for energy efficiency incentive schemes, advanced alternative technologies and support for renewable energy. Benefits would include lower business costs, higher productivity and improved competitiveness.

The administrative cost of the existing negotiated energy agreement (NEA) schemes will be high for government and business. The alternative scheme proposed here would be simple to administer, and the costs for mandatory auditing and verification of claims for discounts as proposed now for NEAs would be saved. Energy intensive sectors with an energy management system (EMS) would have regular internal SEC audits. As discussed earlier, the information needed is readily available for a site-specific energy report to be incorporated into companies' annual financial accounts.

Recycling the revenue from the modified CCL within definable energy-intensive sectors of manufacturing would meet many of the needs of British industry *and* the government. The scheme would:

- reduce carbon emissions without closing energy-intensive industries;

- encourage investment and take-up of new energy-efficient processes and technologies;
- raise productivity;
- cause the closure of firms that do not respond to the call to improve energy efficiency – further reducing carbon emissions because the business will be transferred to more energy efficient firms;
- increase the international competitiveness of British manufacturers.

The stick (CCL) must be applied and the impact of the blow must not be cushioned except by the castigated who can reduce the impact by moving in the right direction. The possibility of a carrot (grants or tax breaks) will give the necessary encouragement thereafter to *continue* in the right direction. DEFRA can estimate the total revenue that would be collected from each sector. A small portion – 10% for example could be put into a technology R&D fund solely for the sectors from which it is collected. The whole of the remainder could be made available for investment grant schemes, or to fund tax reliefs, or a combination of both. Such a strategy would encourage no-cost measures in response to the first phase, followed by all cost effective (ACE) measures. This could virtually eliminate any financial impact on manufacturing costs.

Grants and tax allowances would encourage investment in new energy efficient processes and equipment as each phase approaches. In the later phases of the CO_2 emissions reduction programme – moving towards the all technically possible (ATP) scenario, would reduce SEC *and* carbon emissions. Also, it would increase productivity and competitiveness as computerisation did in the 1980s onwards. Resource savings from improved productivity then can be invested by companies in technologies to produce further savings. Attractive tax incentives should be offered to companies that take the ATP route to energy efficiency.

To gain time to study future policy changes without reducing the impact of the levy over the proposed time-frame, the alternative levy scheme would be introduced incrementally starting at a low rate with no reductions in employers' NI contributions or discounts for negotiated agreements. The revenue could be hypothecated in full. By applying a low initial levy rate, business energy users would become aware of the objectives of the scheme and would be able to plan energy efficiency programmes in anticipation of higher rates before their introduction. Such a scheme would be simple to administer, and reduce the cost to both government and business. But to maximize the effect, it is imperative that wherever possible, most of the revenue from the levy should be reinvested in the sectors from which it is collected.

It is conceivable that higher energy users have much scope to reduce their energy use, without high capital investment or negative impact on their competitiveness. The very energy intensive industries such as chemical, steel, cement, paper and pulp, may have to be treated separately as they comprise some of the country's largest enterprises and are important economically and strategically. These could even be excluded from the general scheme and 'benchmarked' against the best international standards and the carbon-linked tax or levy applied only to any shortfall from best practice standards. Alternatively, large energy intensive companies could be forced to participate in the emissions trading scheme.

Energy intensive sectors could be treated individually for sectoral energy efficiency assessments. The assessments should be based on properly gathered operating data along the lines of the case studies for this thesis – but on a wider scale. After deduction of a portion of the revenue from the levy for development of alternative energy technologies and energy efficient projects, the balance could be ring-fenced for redistribution as incentives for energy efficiency improvement projects within the sector.

Summarizing, the proposal is a revision of the present arrangement. Levy discounts would be unnecessary since an augmented levy would enable business to prepare and adjust for later phases of the scheme avoiding adverse economic impacts. However the scheme must be structured to reflect the *real* potential for reducing the SEC in all sectors of business.

5.2.2 Reduction targets

Setting targets that can be met easily may be good psychologically for achievers but may not meet set goals. Setting high emissions reduction targets and then designing strategies to achieve them, may need stringent regulatory measures and their strict enforcement. For example, the government's 20% CO_2 emissions reduction target is unlikely to be reached unless there is strong political will to push forward policies that may be unpalatable to both business and the populace as a whole – particularly if the UK appears to be going beyond its international commitments when other countries are not. In which case, the government would have to justify the target and that would mean that the government would have to be more explicit and disclose the *real* agenda if indeed there is a hidden one.

High sector targets could be set to drive emissions reduction initiatives harder. A high target may not be achieved, but emissions reductions in excess of the legally binding commitments may be achieved. For instance, if the UK reduces CO_2 emissions by 15% and not the government's target of 20%, it will be invaluable to the national economy and make a significant contribution to emissions reduction. Whilst this would be highly commendable and perhaps acceptable to the policy makers, it may be perceived by critics as failure for the government and *that* may be a political price that is too high – even for a government with some 'green' credentials.

Targets must be demanding to encourage not only better energy management, but also to encourage the take-up of new technologies. Sectoral reduction targets should be assessed on no cost, low cost and all cost effective (ACE), and all technically possible (ATP). The alternative to SEC targets are 'absolute' reduction targets for which energy use or emissions are simply reduced compared to levels of a baseline year by 2010. This could lead to undesirable effects if companies simply reduce output and possibly transfer production to 'non-Kyoto' countries.

'Top-down' targets could be developed and applied as the first stage of future emissions reduction strategy, but there must be sufficient operational data available from business for sound assessments to be made this way.

Specific energy consumption is based on the amount of energy used but the energy to produce a quantity of product. If output rises, SEC should fall as a consequence since process energy efficiency increases with productivity. Conversely, when output falls, SEC rises. The relationships between output and energy used are not always proportional as product mixes vary. Some products require more process energy per unit of output than others do. The fixed energy losses from process equipment may be constant – regardless of product weight or size and throughput. Therefore the energy used per unit of output would be higher for smaller items than large ones for example. Although the accounting procedures are complicated, adjustment factors have been devised to deal with such distortions. (ETSU/DETR, 2000)

The adjustment factors not only allow for variations in product mix, the targets derived also allow rising output. Economic growth increases the total use of energy by manufacturing sectors but at the same time should lower SEC. Any gap between the UK's energy intensity (energy used per unit of GDP), and that needed to meet the CO_2 emissions reduction target would have to be met by alternative low carbon or carbon free energy.

As an energy reduction policy develops, 'milestone' targets can be reviewed in the light of energy and output data from companies in all business sectors to provide representative sector specific assessments. This should avoid unacceptable pressures on individual sectors and organisations. Sectoral targets will have to be adjusted periodically, possibly every two years. The revised targets would be dependent upon the reductions achieved over the preceding periods and the scope for further reductions without adversely affecting international competitiveness of business.

5.2.3. An alternative levy scheme

It may be assumed that the government believes that the present levies will effectively meet its CO_2 emissions reduction targets. Therefore levies should be retained, at least in the short-term. But there should be no reductions in employers' NI contributions to neutralize the economic impact on business as a whole. Unless companies invest the savings from reduced NI reduction contributions in energy efficiency projects, the CCL in its present form will not encourage energy efficiency for companies with net financial gains. The levy should be applied to *all* business energy use. The NI reduction should be scrapped since it is discriminatory in its effect and does not encourage energy saving in low energy using organisations with large numbers of employees.

All CCL revenue should be hypothecated by the treasury to fund incentives for renewable energy schemes and development of renewable technologies and R&D and tax incentives for the implementation of energy efficiency technologies by business. This would introduce the business community to the government's philosophy and would increase awareness of the commitments – without imposing undue economic burdens that could reduce competitiveness. It would allow time to design the subsequent phases and importantly – for business to prepare for them.

A timetable along the lines discussed, would allow industry to plan and a well co-ordinated presentation of the revised strategy would:

- increase awareness of the issues of climate change and emissions abatement;
- give a clear signal of the government's intent without being construed as a 'u-turn'; and
- give time for business to adapt.

Even with a small and gradually introduced tax, some SMEs could have special problems with the transition to each new regime. Cash flow in SMEs is often very precarious and additional costs can easily lead to insolvency. To reduce financial impacts of the existing scheme, Baron (1997) proposed that SMEs should have an initial levy-free amount of energy beginning at quite a high level and then gradually reduce to a pre-announced timetable. This would be complicated to administer, create anomalies and would be unworkable in the longer term. The alternative approach proposed here would obviate the need for such concessions

When considering special treatment of SMEs, care must be taken to avoid circumstances that would encourage setting up smaller manufacturing units in order to reduce the levy. This would reduce efficiency of scale without reducing emissions. Also, any special treatment for SMEs could give the wrong signals that would reduce the effectiveness of levies.

Until there is sufficient evidence to indicate that the reasoning behind the abatement policy needs major amendment, all sectors of the UK economy should be expected to make some contribution to the 20% reduction in CO_2 emissions. (Transport and domestic sectors are treated separately and are outside the scope of this work).

A levy should be applied to the business sector as a whole as now but without reduced employers' NI contributions or discounts for NEAs. Levies will be set at low initial rates and augmented in phases until 2010. The proposed scheme is outlined here with suggested distributions of revenue and future measures. The levy rates are those applied in the spreadsheet model experiments,

Phase 1. 2002-2003:

- CCL re-set at approximately 20% of existing rates.
- The levy will be applied with no exceptions in the first phase.
- Revenues will be hypothecated for the business sector as a whole.
- The revenue from the low energy using sector will be recycled as funding for R&D into renewable energy systems and enhanced capital allowances (ECAs) for a wider range of approved energy efficient goods.
- The revenue from the energy intensive sectors, for example those that have NEAs under the existing scheme, will be re-distributed within discrete sectors as grants and tax concessions for energy efficiency schemes (including EMS costs), and energy efficient technologies.

Phase 2. 2003:

- The CCL is raised to approximately 40% of existing rates.
- 75% of the revenue from NEA sectors will be hypothecated as tax incentives, the balance will be used to fund energy efficient technologies R&D.
- The revenue from the low energy intensive sector will be used to fund R&D into renewable energy systems and enhanced capital allowances (ECAs) for approved energy efficient goods.
- If feasible, highest energy intensive industries, such as iron and steel, paper and pulp, cement for example, should be treated as special cases using international benchmarks for performance standards which if met could be rewarded by discounted levy rates or joining the emissions trading scheme.

Phase 3. 2004-2006:

- Levy raised to approximately 70% of existing rates – applied to all business except for those sectors exempted in Phase 2.
- 75% of the revenue will be hypothecated within each discrete sector as tax incentives. The balance will be used to fund energy efficient technologies R&D.
- Apply a renewable energy levy to all energy bills – including domestic. This would be a portion of the CCL for business users.
- Introduce emissions trading schemes for energy intensive sectors.

Phase 4. 2007-2010:

- Expand emissions trading.
- Review CCL and adjust in the light of effects of Phase 3, or introduce carbon based energy tax. Existing levy rates were applied in the model for Phase 4.

Phase 1 of the scheme will reinforce the government's call for business to reduce energy related CO_2 emissions without seriously affecting competitiveness. This is crucially important at a time when sterling's strength is adversely affecting UK manufacturing industries.

The firms that have signed up to NEAs under the current scheme, will be able to claim grants towards the cost of their energy management system to which they are already committed. All companies will be able to apply for grants and tax relief for energy efficiency projects. The economic impact of the levy will be neutral for all firms that respond appropriately.

The cost of the Phase 1 levy *without discounts* or reduced NI payments can be ameliorated by business in general by implementing no-cost measures. This phase would not impose a more significant economic burden than the present scheme and would raise awareness of the need to reduce energy related CO_2 emissions, and allow time for business to adapt in order to mitigate the impacts of future higher levy rates.

All of the revenue would be hypothecated for investment in energy efficient technologies, renewable energy schemes and R&D grants. The revenue from energy intensive industries can be ring-fenced for the sectors from which it is gathered and used as tax incentives to encourage investment in more energy efficient equipment and energy management systems.

Phase 2 lasts for one year for which the levies would be raised to 40% of the existing rates. Distribution of revenues would depend upon the success of Phase 1. The increased revenue raised from Phase 2 could be used to fund increased rewards for firms that responded appropriately. For example, 50% of the revenues could be recycled as tax incentives for energy efficient investments by energy users. A portion of this part of the revenue should be ring-fenced for either energy intensive industry as a whole, or if practicable, for individual sectors. Twenty-five per cent could be set aside for process technology R&D. The balance could fund renewable energy schemes and research into renewables. This would encourage increased involvement of a wider section of business in preparation for the next phase.

The third phase of three years follows the format of Phase 2 but with higher levy rates. The first three phases would allow time to prepare for the introduction of more complex instruments – carbon-based taxes and emissions trading.

Phase 4 could be designed to incorporate the advantages of the earlier phases and balance the emissions reduction account by 2010. If necessary, a modified levy scheme could be introduced in light of structural and economic changes, and reflect business-energy market prices. By the start of Phase 4, there should be an efficient and effective emissions trading system that could be expanded to include all firms that wished to participate as an alternative to paying a levy. During Phase 4, the levy or alternative economic instruments could be adjusted annually in the light of progress towards the 2010 target.

The mix of economic incentives would depend upon the conditions prevailing and in the light of the outcome of previous phases. Probably at least half of the revenue gathered from energy intensive sectors should be recycled as tax breaks and grants for investments in energy efficient technologies within these sectors. The balance should be used to fund R&D for energy efficient manufacturing processes but not in renewable energy technologies. It is unreasonable for the industrial sector to fund renewable energy schemes via the CCL. Funding for renewables should come from the exchequer since it is in the interest of all energy users. As proposed previously, a renewable energy levy should be applied to all energy bills - including domestic.

For the model, during Phase 4, the final four years to 2010, the levy is raised to the existing level. This would be punitive for the firms that had not responded to the call for energy efficiency improvement.

Data from the case studies in aluminium foundries and the results of the experiments made in the spreadsheet model show that an alternative incremental levy would meet the government's present specific energy reduction target for the aluminium casing sector. It is likely that the findings for the aluminium casting sector can be extrapolated for the foundry sector as a whole. Furthermore, many aspects of the foundry sector are typical of other industries that use significant amounts of process energy. The research undertaken in the aluminium foundry sector could be replicated for the foundry sector as a whole (all metals), and other business sectors that have climate change levy agreements. It may be that similar patterns of energy efficiency apply and there are potential energy savings of a similar order.

Advantages:

- All businesses are treated the same way regardless of size.
- The scheme eliminates discrimination and ensures fairness.
- It will encourage good behaviour and penalize bad.
- It is simple to apply.
- It is easy to administer.
- There is no need for verification and third party auditing.
- There are no loopholes for cheating.
- EMS can be voluntary and informal to minimize cost and administrative burden.

- Reporting could be mandatory for large enterprises and encouraged for SMEs.
- Emissions trading can be developed to embrace all sizes of enterprise.
- Documentation will be minimal.
- It will allow flexibility for the government and time to address anomalies, and give scope for fine tuning.
- Progress can be measured easily.
- Simple reporting procedures for site specific energy consumption.

'Milestone' assessments can be made against sectoral and overall progress targets for each phase. The effectiveness of the strategy can be assessed and revised as necessary to ensure that the final targets will be met. The levy can be adjusted annually if necessary to take account of price and structural changes in energy markets The revised strategy should encourage ACE measures and subsequently ATP.

It could be argued that it is too late to start again, but there is no explicit strategy now. The only immediate change proposed here would be the amendment of the existing climate change levy, which in its present form is unlikely to meet the government's emissions reductions objective without damaging the competitiveness of British industry and the attendant risk of moving business abroad.

5.2.4. Discussion of alternative levy scheme

The effect of energy prices on energy efficiency was discussed in Chapter 2. In theory, as energy prices rise, either as a result of market forces or the application of economic instruments, incentives for energy saving to offset the economic impact increase. There are some unavoidable costs associated with improving energy efficiency, but after the initial phases of energy improvement programmes, the ongoing costs should reduce and thereafter stabilize as will specific energy consumption. This simplified 'cause and effect' proposition is illustrated diagrammatically in Figure 5.2.

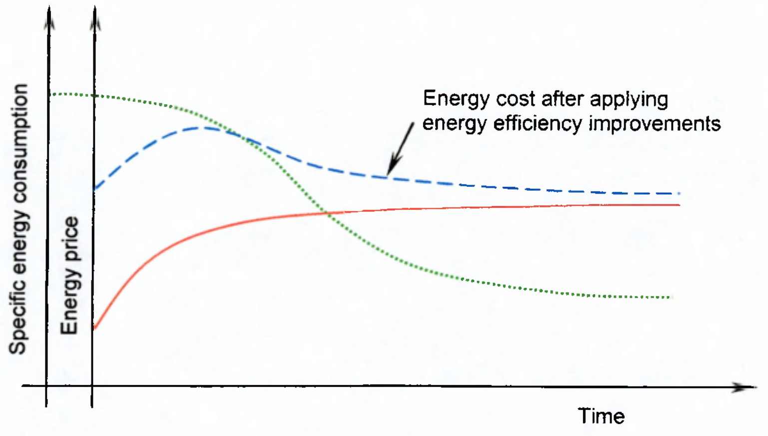


Figure 5.2. ***Chart showing effect of rising energy price against specific energy consumption.***

The notional model Figure 5.3 shows that there is a point at which the cost of improving energy efficiency exceeds the economic benefits that can be derived. But the economic balance depends on the cost of energy. It is therefore feasible for the government to shift the balance point by varying the cost of energy using economic instruments. For example, if at the point of economic balance business energy use ceases to fall, the levy could be raised to reposition the point of balance to encourage further response, *but without imposing an unacceptable burden that would impair international competitiveness*. This is the theory upon which the argument for an incremental levy scheme is based.

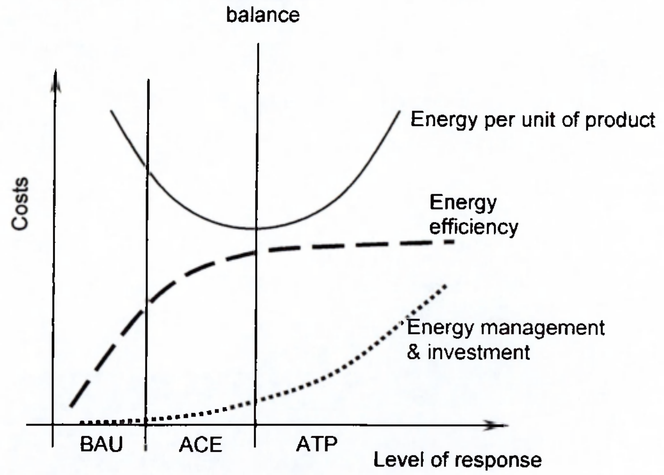


Figure 5.3. ***Notional model of energy efficiency costs.***

The application of levies should have an immediate negative impact on profitability for business energy users. But the business as usual (BAU) approach whereby no-cost or low cost measures are taken to reduce energy use, eventually offsets the cost of the levy and profitability will be restored to pre-levy values.

Companies that invest in all cost effective (ACE) energy saving measures would suffer the immediate effects of the levy *and* investment costs on profitability. But the costs will be recovered and thereafter profitability will rise.

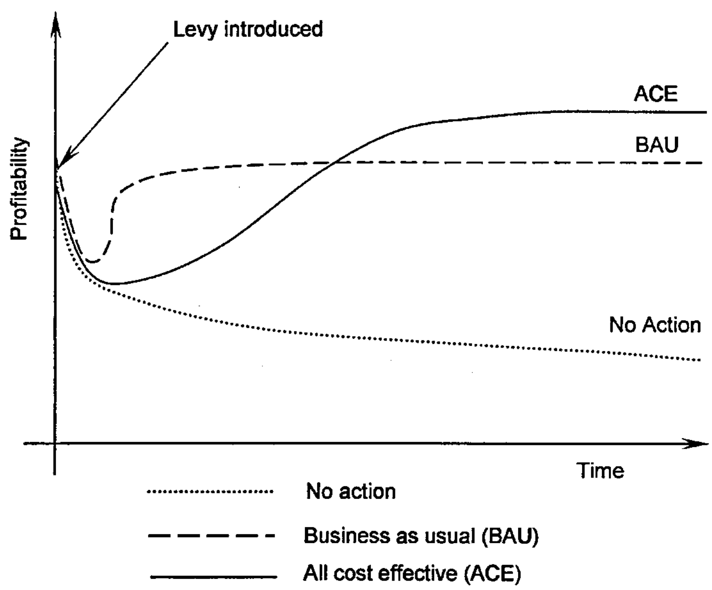


Figure 5.4. ***Chart showing effects of levy and countermeasures on profitability.***

The effects of the levy on companies' profitability will depend upon their response. Figure 5.4 represents three possible responses. Those that take no action to improve their energy efficiency will have the full impact of the levy on their operating costs. This will reduce profitability, or if they attempt to recover the additional cost by raising their selling prices they will reduce their competitiveness, losing business to those that do improve energy efficiency. There is a risk that some of the competition is from other countries that are not committed to reducing CO_2 emissions. In which case, the source of energy-linked carbon emissions will merely move abroad and rather than reduce may even increase. Such 'leakage' must be avoided.

It would be unacceptable to impose any form of sanctions on imported goods from developing countries that are not expected to reduce greenhouse gas emissions in the immediate future. Therefore, other ways must be devised to encourage energy efficiency and maintain UK competitiveness. If the punitive effects of economic instruments are not sufficient to encourage more efficient energy use, then they should be complemented by other economically attractive incentives (carrots) to stimulate investment in energy efficiency.

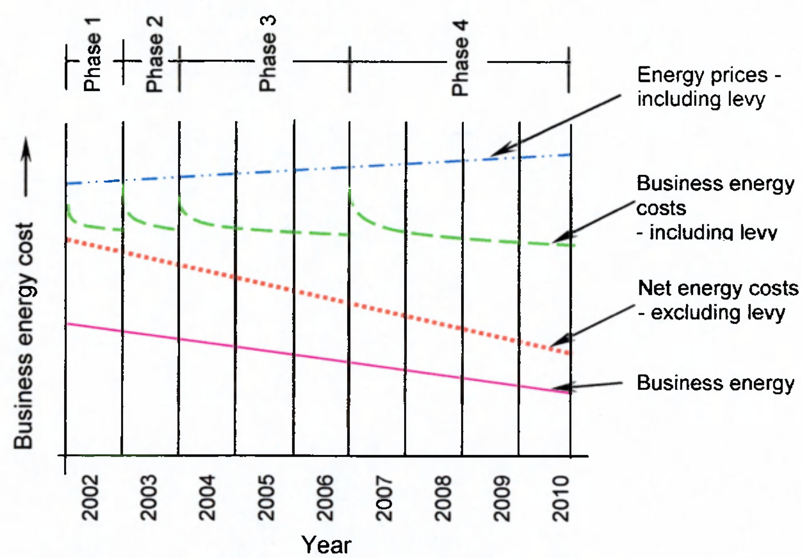


Figure 5.5. ***Chart representing effects of incremental levy and improved energy efficiency on business energy costs. (Fixed energy price basis).***

The chart (Figure 5.5) shows the possible influences and effects of an incremental levy on business energy use as proposed and used in the spreadsheet model discussed in Chapter 4. At the start of Phase 1, the levy will add to business energy costs. Over the first one year period, businesses should take measures to improve energy efficiency to alleviate the impact of the levy and energy improvement costs so that energy costs would fall to the net pre-levy costs. This would be repeated over each phase.

Although energy *prices* will be increased by the levy, overall energy *costs* should remain substantially unchanged, (except for the effects of changes in net prices). At the same time, energy use will fall.

5.2.5 Scheme applied to aluminium casting sector

Prior to the introduction of the CCL and sectoral agreements, ETSU estimated that the SEC of the cast metals sector could be reduced by 21.0% below the 1998 baseline. The results of the author's work described in Chapter 4, show that the original ETSU target was not unreasonable. (Tables 4.12 and 4.13) However, the sector responded by claiming that ETSU's figure was unrealistic and that only 5% was possible. (BMCA, 1999) This was rejected by the DTI and the foundry industry carried out an audit programme that showed 7.8% was possible. Under pressure from the industry, the DETR compromised and set the sector's target at 11%.

An incremental levy scheme for which Phase 1 levies set at 20% of the existing rates, (Chapter 2, Para. 2.6.6), would increase average industrial electricity costs by approximately 3% and gas by 1-2% from 2001 prices. As shown in Chapter 4, this could be abrogated easily by the aluminium casting industry. Imposing Phase 2 levy rates would double the cost increases, Phase 3 rates would add approximately 10% to electricity and gas costs. For Phase 4 when the existing levies are applied in full, energy costs will be approximately 14% higher than 2001.

5.3 Implications of augmented levy

The introduction of the climate change levy in 2001 coincided with a critical phase in the economic cycle; manufacturing output was falling and sterling was strong against the euro. By late in 2001, manufacturing was officially in recession and energy intensive industries, particularly those dependent upon the automotive sector were badly affected. The cost of the levy added to costs at a time when casting suppliers must respond to 'cost-down' demands from its major customers, the continuing weakness of the euro affecting competitiveness, and when emerging Eastern European economies present a serious threat to the industry in its main markets. Although not all industries are dependent upon the automotive industry, replication of the impacts outlined here may show that other energy intensive sectors and manufacturing in general will be affected in a similar way. The alternative levy scheme proposed here would at the very least preserve the status quo.

5.3.1. Feasibility

All sectors of the economy are expected to contribute to achieving the greenhouse gas and CO_2 emissions reduction targets. It would be unreasonable to expect all sectors to contribute equally and account must be taken of the scope for reductions to avoid undue burden on any one sector. It is important to bear in mind that the target does not have to be met until 2010. In the intervening years there should be ample time for the government to devise an augmented levy scheme and adjust it in the light of results. As the CCL is already in effect, there will be no time lost if a modified scheme is introduced. There is time to produce a workable scheme based on the strategy presented here. The only change to the present levy arrangement would be the application of fixed levies for all businesses, and re-instatement of the employers' national insurance contribution by raising it by 0.3%.

5.3.2 Potential impacts on UK manufacturing

All national policies have political, economic and societal impacts – some direct, others indirect. The government is obligated to ensure that any unfavourable impacts of its policies are minimized. The hypothesis offered here would meet the obligation *and* the UK's commitment to the Kyoto target.

Most of the objections to energy taxes, such as the potential negative impacts on competitiveness and unemployment, could be overcome by:

- careful design of taxes or levies;
- the use of respective revenues as part of policy packages and green tax reforms;
- gradual implementation; and
- consultation with all parties concerned.

In addition to their environmental effectiveness, climate change levies should encourage innovation and competitiveness for UK companies. Early reviews of the existing CCL would reveal the scheme's effectiveness and with a view to the wider application of economic instruments for environmental policies. More evaluation studies of economic instruments should be carried out.

5.3.3 Reduction of emissions

By 2001, UK CO_2 emissions had reduced by 6% below the 1990 level. The explanations of the reductions were documented in Chapter 2. To meet the Kyoto commitment a further 6½% reduction is expected – that is almost 7% below the 2001 figure. To achieve the unilateral target of 20% means that 2010 CO_2 emissions must be 15% lower than 2001. Under the present scheme, the task of reducing emissions by these amounts will be difficult without adverse impacts on manufacturing. It has been shown that overgenerous compensation by lowering NI contributions has obviated the financial need for many businesses to reduce energy use immediately.

The responsibility for reducing energy use should be shared fairly between all sectors of the economy taking into account the ability to contribute. If it is assumed that except for a few special cases such as iron and steel, all sectors can make equal contributions, regular assessments will reveal weaknesses *and* strengths of the present scheme. In the light of findings the strategy can be refined and adjustments made as necessary to compensate for deviations from progress targets.

Progress towards the reduction targets must be monitored regularly. There are several ways in which the information can be gathered. Business could be encouraged to report annually on output and energy use. Energy suppliers could provide statistical information on deliveries to business customers analysed by sectors using SIC codes. Trade associations can provide output figures. The Cast Metals Federation for example can produce output data for each metal cast by members. It would be simple for members to report their energy consumption. Member companies could be asked to make 'self assessment' reports on their specific energy consumption.

It is vital that adverse impacts on UK business activity are pre-empted if the government is to achieve the environmental and economic objectives of sustainable development. This will only be possible with co-operation from business by providing statistical information and informed assessments of the state of trade and evidence of trends.

5.3.4. Government policy

Concern for the future of the earth and the welfare of future populations have gathered momentum over recent decades. In 1988 the UN set up the Intergovernmental Panel on Climate Change (IPCC), to disseminate all available information on the threat of climate change due to global warming caused by increasing levels of greenhouse gases in the upper atmosphere. IPCC (1995) concluded that there is a balance of evidence to suggest that there is a discernible human impact on global climate. This led to calls for action, especially by developed countries whose industrialisation is purported to be the primary cause of the rising levels of greenhouse gas concentrations in the atmosphere. There is evidence that the levels are rising at an increasing rate, largely due to industrial activities in developing countries.

As a result of growing concern, decisions have been made to address the threat by reducing the greenhouses gases emitted by developed countries. Although the Kyoto Protocol has not been ratified by all signatories – the most notable defaulter being the USA – the UK together with other European Union member states has committed to accept its share of the first reduction targets. The UK government also made a unilateral commitment to reduce carbon dioxide emissions by 20% below 1990 levels by 2010.

If global warming due to an enhanced greenhouse effect does not occur, reducing energy related greenhouse gas emissions is a worthy challenge. Economising on fossil fuel derived energy use will strengthen the UK's future energy security by reducing the dependence on imported fuels. There are valuable economic benefits from higher energy efficiency – the potential for exports of energy efficiency technologies that will be developed, and reduced manufacturing costs are two examples.

The aims of the various political initiatives are to improve the quality of life of the earth's existing populations, and to ensure that the life of future generations is not impoverished by the unnecessary depletion of resources including non-renewable fuels. But a global consensus on environmental issues will be possible only when the social and economic consequences are acceptable. This can be achieved by creating a balance between environmental, social and economic issues. At this time, the onus of reducing global warming falls mainly on the developed world. By accepting this responsibility, *developed* nations give a strong signal to *developing* countries, that a more sustainable energy policy is essential for global economic growth and an orderly evolution of the world.

Economic development in an ecologically damaged environment is not feasible; but a global consensus on environmental issues will be possible only when the social and economic consequences are acceptable. This can be achieved by creating a balance between environmental, social and economic issues. Schumacher (1973) believes that the overwhelming priority given to economic growth is unsustainable and disastrous to environment and society. However, sustainable growth should be achievable, either through efficient use of resources, or limitation of goals. Since the latter would be unacceptable to modern society, the former is the only option – *doing more with less*.

The global economy is a complex matrix of economic and political links, some direct, some indirect. Each nation has its unique political system. Each has economic policies and strategies by which to achieve its goals. The wealth and economic strength of nations depend upon many factors including – industrial maturity, availability of indigenous resources, geographical location, climate, infrastructure, population size and distribution, and education standards. However, all nations are economically inter-dependent today since there are few major barriers to international trade in goods and services. Furthermore, the globalisation of business through multinational companies and intergovernmental and institutional co-operation has a profound influence on international politics and economics. National environmental policies, strategies and performances are all to some degree also dependent upon these diverse influences.

It is clear that the UK economy cannot operate in isolation and energy policies need to be designed to react slowly to short term changes such as world energy prices and variations in economic activity – but it is important that such policies are adapted to accommodate long-term changes as they are identified. The long-term benefits from policies to reduce carbon dioxide emissions may vary widely from any short term achievements, but the government should set concise short, medium, and long-term targets for energy supply *and* energy use. In the past, energy policies have not been clear nor have the strategies for their implementation. Achievements in energy efficiency improvement, whilst worthwhile, have not been as good as they might have been with better planning.

Events shape government policy rather than foresight, and technological change occurs at the rate of acceptance rather than the rate of technological advance. Meadows *et al.,* (1972:148), said, "While technology can change rapidly, political and social institutions generally change very slowly. Furthermore, they almost never change *in anticipation* of a social need, but only in response to one". The government should allow for business's delayed acceptance of and response to the need for change, and design its policies accordingly. A prolonged delay may present even greater difficulties to achieve sustainable development and tackle the threat of climate change.

To respond to events and advance its objectives, the government needs to:

- *sustain and strengthen* interest in energy efficiency by having rational, well publicized policies;
- *develop a balance* in business's enforced responsibilities for environmental protection;
- *contain the economic* commitments associated with environmental protection;
- *enhance the capabilities* of government agencies, infrastructure, human and intellectual capital, and science and technology;
- *evaluate continuously environmental strategies* in changing economic and political climates.

There may be increasing pressure from within government and the wider community to justify major amendments to the current levy arrangements or even an alternative strategy.

If there is justification for change, it is crucial that time is not lost before taking the requisite steps to introduce policy changes. By reacting to circumstances and possible pressure from the environmental lobby, such a course of action should not be construed as failure of government policy, but rather that of pragmatic management.

However, managing energy policy will be challenging for the current institutional set-up which may be inadequate to manage economic instruments and the growth in sustainable energy systems that will be needed over the next decade to meet the government's environmental targets. The present arrangement may not be appropriate to manage the changes that will be required to integrate effectively climate change, sustainability and related environmental issues into government policies.

Prominent among critics of the existing arrangement, Green Alliance (1999) advocated a radical institutional change and called for a UK sustainable energy agency to co-ordinate government policies. Green Alliance (GA) stressed that the implementation of policies to meet the government's 20% CO_2 reduction target needs greater priority than it receives at present. It believes that a new body would be a sign of the political support that is necessary to deliver the targets. An overriding argument against the present piecemeal approach is that the current UK and international targets are only the beginning to meet the long-term need to lower greenhouse gas emissions. In this context, it is essential that the correct government structures are in place if stricter future targets are to be achieved and a single agency might be more effective to initiate policies. The government in response acknowledged that there could be significant opportunities for GA's ideas. As the report is relevant to *this* discussion, many of its aspects are raised here.

Energy conservation programmes initiated in the 1970s were undermined by lower prices in the decades that followed, particularly after privatization of the gas and electricity supply industries. Without a coherent energy policy there has been flagrant waste of energy resulting mainly from a lack of pricing structures for indigenous oil and gas resources. Whilst the national exchequer benefited directly from the sale of exploration licences and indirectly by tax revenues from energy companies and energy users, some of the longer-term economic and strategic benefits may have been lost. The UK Department of Energy was disbanded in 1992, so that the DTI and the Department of the Environment (later to become the DETR and now DEFRA), share responsibilities for energy policies.

GA endorsed the formation of the Cabinet Office Performance and Innovation Unit and Cabinet Committee on sustainable energy, to facilitate strategic planning and resolve conflicts between the plethora of agencies that are involved now. GA suggests that the UK could follow other countries, and create an agency that would operate independently of government as in other EU countries, for example the Danish Energy Agency (DEA) and the Dutch Energy and Environment Agency (Novem).

DEA has significant responsibilities for preparing and evaluating policy options, initiating legislation and regulations, and managing implementation. In addition, Denmark has integrated fully its energy and environment ministries into a single ministry. The Energy and Environment Minister has authority for the implications of agreements with the energy industry. This is not the case in the UK where the DEFRA is subordinate to the DTI on a range of energy related matters.

Novem, has major responsibility for the implementation of a wide range of Dutch environment and energy policies. The policies include negotiated agreements with industry, grants and subsidies for all sectors, and implementation of policy measures to encourage CHP and renewable energy. The Dutch agency also inputs to tax credits and energy taxation systems. Financial support is provided by four government ministries. The agency claims that it has been instrumental in doubling the rate of energy efficiency improvement in the Netherlands in ten years. Unlike ETSU, Novem has major responsibility for policy analysis, discussion and implementation, and greater budgetary resources.

To be effective, a new UK institutional arrangement must have powers to co-ordinate policies; have substantial political authority and a high public profile. But Green Alliance questioned if a new institution was really needed or whether the government could give the responsibilities to an existing agency. Although there are problems with the present institutional structure, it would be easier and more effective in the short-term to restructure existing agencies.

5.3.5. Economic

After deregulation of the energy industry, every business in Britain could reduce energy bills without investing in energy efficiency measures, simply by negotiating better tariffs with energy suppliers. The fact all business energy users gained financially from the competitive supply market has not encouraged efficiency improvement. Since deregulation, UK industry has had significant economic benefits from low gas prices but the benefits reduced financial stimuli for energy efficiency and reduction in energy related emissions.

The underlying 'energy policy' in most firms has been based on reducing the cost per unit of energy, rather than reducing the quantity of units used. One reason may be so called 'energy efficiency policies' are often championed by the purchasing or accounts departments and are based purely on the benefits of cost saving.

There is a case for regulated energy prices, so that the cost savings enjoyed by 'playing' the energy markets would not exist. Reducing actual energy consumption would be the only option for minimising energy costs. Energy managers would then concentrate on the job of *managing* energy and not *buying* it.

Purchasing managers (buyers), have responsibility for buying energy and other consumables at the lowest prices possible. The performance of the purchasing department is usually measured by its control of costs of goods inputs. The performance of energy managers should be measured by their control of energy use rather than its cost. If energy managers reduce energy consumption, buyers also will see the benefits from lower energy costs. There would be an incentive for buyers to encourage energy managers to improve energy efficiency. Perhaps buyers should be energy champions.

Industrial gas prices fell in real terms by 45% from 1990 to 1999. Electricity prices fell by 26% from 1990 (privatisation) to 1999, and according to Macarthy (2001) electricity prices fell by 20% over the period 1997 to 2000, 10% being in 2000. Warren (1997) claims that total energy demand rises by about 4% for a 10% fall in energy prices. The fall in fuel prices following privatisation led to a 5% increase in industrial emissions of carbon dioxide. Warren blames price reductions for a 4% increase in electricity use and 2% increase in gas use, and argues that this added 3.5 terawatts of energy consumption that otherwise may have been avoided had real prices remained constant. It is estimated that this in turn led to 9 million extra tonnes of CO_2 being released into the atmosphere in the three years preceding 2000 – 3 Mt from additional electricity use and 6 Mt from gas.

However, competitive energy markets encourage better services and innovation in the energy production and supply industries. There are economic benefits from lower energy prices but there is conflict with environmental objectives. Until 2000, UK industrial energy prices were low compared to those of European competitors. Consequently, the financial incentive for energy saving was low. Recent energy prices rises encourage energy efficiency, but market forces cannot be relied upon for prices to remain at this higher level in the longer term. Therefore it is reasonable to deduce that prices have to be raised artificially either by carbon taxes or duties such as the climate change levy on business energy use.

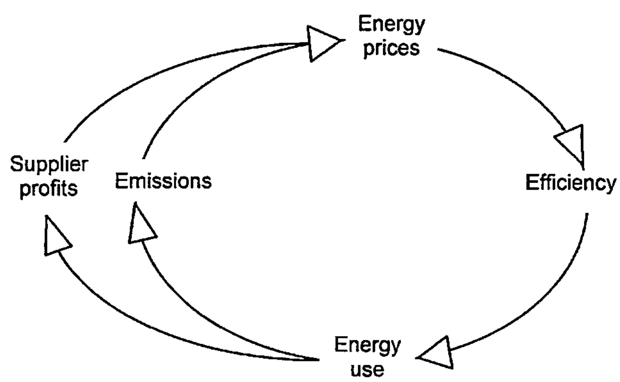


Figure 5.6. ***Energy price causal loop diagram.***

If energy prices rise, energy efficiency should rise and consumption should fall. As Figure 5.6 shows, there would be a two-fold effect, energy related emissions would fall, but energy suppliers' profits would fall also because of lower turnover. The cost per unit of energy would be increased by suppliers to recover the fixed costs of extraction, generation and distribution on lower sales volume. The cause and effect cycle would be repeated until energy efficiency improvement was no longer economical, at which point consumption, emissions, profits and prices would stabilize.

If the UK is to meet its emissions reduction targets, the government could not wait for energy prices to rise naturally from market forces. Time would have been lost, time that is critical if the UK is to meet the set targets without undue impacts on the economy. It was imperative that the economic instruments were applied as early as possible; even now it could be two or three years before such measures begin to influence energy use. It could be well into the decade before the effects will be significant, leaving considerably less than ten years in which the targets are to be met.

All energy users pay existing taxes linked to energy use. The transport industry and all road users pay value added tax (VAT), and duty on fuels. Business pays VAT on energy. All value added taxes and duties are eventually borne by the final consumers of goods and services. Unless manufacturers offset the CCL by energy efficiency improvements, *it* also will be reflected in prices paid by final consumers. This will only affect prices of goods of UK origin. Higher prices will reduce the demand for domestic production, lowering output and manufacturing efficiency. Although the UK energy related CO_2 emissions would fall, energy intensity of UK GDP will rise. Economic growth will be lower. If the imported alternatives originate from countries with lower energy efficiency, the effect could be an increase in global emissions. UK exports would be adversely affected and the balance of payments deficit would rise. This would have a severe economic impact on the UK economy. The economic impacts of the alternative levy scheme proposed here would at least be neutral for enterprises that reduce energy use.

Many environmentalists advocate a carbon-based emissions tax as an alternative to the CCL to promote energy conservation *and* the use of renewable energy. An emissions-based tax would encourage changes in product and process technologies to reduce the amount of fossil fuels consumed. If technologies exist that allow manufacturers to reduce fossil fuel consumption without reducing product output, then companies would weigh the cost advantages of paying the tax against the cost of such technology.

Eco-taxes do not provide all of the solutions either for environmental problems or for business prosperity but they have to be considered. Carbon taxes or other economic instruments are probably the most efficient way to induce the optimum response to meet commitments to carbon emissions reduction. But other measures may have to be considered – measures such as fuel-use restriction, other economic instruments, including subsidies for appropriate R&D, regulated energy efficiency standards, more voluntary agreements with energy intensive sectors of industry, and an inclusive emissions trading scheme.

5.3.6. Societal

By raising public awareness and creating a culture around energy conservation and the associated environmental benefits, it may be possible to stimulate more interest in business energy efficiency and establish energy efficiency in business ethos. Energy intensive organizations may be compelled to reduce their energy related carbon emissions to meet growing pressure from stakeholders including:

- shareholders and financial institutions;
- insurers;
- national and local government;
- general public;
- customer/supplier chains;
- NGOs;
- environmental pressure groups;
- professional and scientific institutions.

There should be no negative societal effects. In the long term there will be benefits from energy efficiency that will outweigh the short-term costs. Energy economy will reduce the rate of extraction and use of indigenous fossil fuel resources, reducing the dependence on imported fuel which in turn will strengthen national security. Reducing emissions from combustion processes will improve local and global environments. New energy efficient goods and technologies will improve comfort and health. If business raises its energy efficiency, and new energy efficient goods and processes are developed, business will grow, creating more employment and strong economy.

5.4 Contribution of the research

The case studies were carried out to find more detailed information on energy use in aluminium foundries than was previously available. Government policy on energy and its impacts on industry was analysed. This work suggested strongly that an alternative to the existing climate change levy scheme could be beneficial. A model was developed and used to test this.

Uniquely, this model takes account of the scope for improving energy efficiency and the economic effects of a levy, and leads to the conclusions that an alternative levy scheme would:

- encourage energy efficiency;
- meet the energy reduction targets set for the sector by the DTI;
- not impair international competitiveness;
- not impose an undue administrative burden on firms;
- allow all businesses to be treated the same way regardless of size and would not be discriminatory;
- encourage good behaviour and penalize bad;
- be simple to apply and easy to administer;
- need only simple reporting procedures for site specific energy consumption;
- eliminate the need for verification and third party auditing;
- allow flexibility for the government and time to address anomalies, and give scope for fine tuning.

5.5 Limitations

A tax on energy may not be the lowest cost way to meet the commitment to the Kyoto Protocol. The intention of an energy tax is to change behaviour. But if this is to work there must be a carrot as well as a stick. To ensure that business reacts positively to energy levies, the revenue raised should be offered in various forms of financial incentives for firms that reduce their carbon emissions.

To determine appropriate levels of future carbon taxes, the costs and benefits of the taxes must be examined carefully. It is important that the government understands the relationships between the level of a tax and the amount of carbon emissions abated, and between the size of a tax and its impacts on economic activity that could affect GDP.

Meacher (2002) declared that Britain, being one of the first countries to produce a strategy, is in the forefront of delivering on sustainable development. But the quest to meet environmental goals could increase manufacturers' costs if business does not respond by offsetting the energy levy cost by lowering SEC. Jobs could be lost as manufacturing output falls due to reduced demand for UK produced goods in favour of cheaper imports.

The impact of energy tax on the economy as a whole depends on how the revenue is used. If the revenue is distributed outside the business sector in the long term it could lead to a fall in GDP, or to a rise if recycled as incentives for investment by industry.

5.6 Further work

This work and that of others indicate that it should be possible to set benchmarks for energy efficiencies for each sub-process used in the production of castings. Benchmarks could be based on information gathered directly from the industry through accredited agencies and recognized trade associations. The benchmarks could allow for the different influences that affect site specific energy consumption – influences such as company size by number employed, size by annual tonnage, and the post-casting processes carried out in-house. Foundries could be categorized according to the condition in which castings are delivered to customers, trimmed only, shot-blasted, fully machined, heat-treated, or heat-treated and fully machined.

It may be feasible to derive site specific energy consumptions for most UK aluminium foundries. Firms could list secondary in-house processes such as heat-treatment and machining. The sample template in Appendix VI shows how such a scheme could be used to calculate SECs for individual sites, including those for 'mixed' foundries that cast more than one metal and use more than one casting process. The data would enable researches to produce averages for each casting process and justify variations from the average by taking account of the secondary processes. Future sectoral targets could then be based on benchmarks derived from such information.

The work could be extended to other foundry sub-sectors and it may be feasible to derive targets for individual sites, based on benchmarks. It would be easy for foundries to submit statistical returns for energy use and outputs. The information needed to complete returns is readily available from metal ingot and energy suppliers' invoices, and castings despatch notes. In cases where despatch notes do not show weights, then metal purchase invoices could be used to estimate despatch tonnages, allowing for process losses and rejects.

Models similar to that used here for the aluminium casting sub-sector could be designed for other energy intensive sectors of manufacturing to set site specific and sectoral energy consumption targets. Mandatory reporting would not impose a significant administrative burden on companies, in fact such information is prepared by most companies for monthly management accounts. Site specific energy consumption could be included in companies' annual financial accounts and statutory annual returns as in France and Denmark.

The effectiveness of the present levy scheme should be assessed as soon as possible to avoid irreversible damage to the manufacturing sector. A broad study along the lines of that discussed in section 5.3.1 covering all sectors of business would give indications of both emissions reductions from energy intensive industries and the economic gain for low energy users.

5.7 Summary

Climate research programmes are funded by governments. It may be assumed that their scientists are qualified to disseminate the climate data and translate it into relatively simple terms with clearly defined projections and implications. National governments worldwide have accepted that there is a serious risk of global warming. This concern was confirmed at the Rio de Janeiro and Buenos Aries Summits. The Kyoto meeting re-enforced the agreement made at Rio de Janeiro. The protocol was significant in that it demonstrated acceptance of the threat of global warming.

Based on the available evidence, science, engineering and technology can provide some of the answers, it can identify solutions and help to deal with the consequences. Sociologist, economists and politicians also have an important part to play. Current emissions reduction targets may not avoid the risk of dangerous effects from climate change and should not be taken to be effective climate management.

The term 'energy efficiency' may no longer be emotive for business and perhaps 'climate change' and 'sustainable development' will stimulate more interest in the need for energy efficiency. However, such an approach is likely to be ineffective without clear policies and high profile strategies. The alternatives to soft approaches are more stringent regulations and higher economic penalties. There may be sound arguments for such options – particularly as it appears that the majority of businesses only view energy saving in monetary terms. If investment in energy efficient technology cannot be justified by adequate cost saving, then although carbon taxing is a contentious issue, it may be the only instrument available to governments to encourage energy efficiency.

The objectives and benefits of improved energy efficiency may be summarized as:

1. Reduce the gaseous emissions from the combustion of fossil fuels.

1.1 Reduce the risk of irreversible climate change - greenhouse gases;

1.2 Reduce the ecological damage to flora and fauna - acid rain;

1.3 Reduce the risks to health - ground level ozone;

1.4 Reduce the risk of catastrophes such as floods, droughts, etc.;

1.5 Avert the risks of political instability, consequential regional wars and threat of global escalation.

2. Reduce the rate of use of finite resources of non-renewable energy.

2.1 Sustainable development;

2.2 Gain time for the development of non-fossil alternatives;

2.3 Extend the economic benefits from UK fossil fuel resources.

3 Reduce the need for more power generating plant.

3.1 Conserve the energy and materials needed in their construction;

3.2 Deploy the conserved resources in other energy saving projects such as infrastructure and technology research.

4 Reduce energy costs.

4.1 Maintain current competitiveness of UK manufacturing;

4.2 Improve *future* competitiveness of UK manufacturing.

Hawken *et al.,* (1999) predict that during the next half century there will be a "new industrial revolution" as radical and far reaching as that of the eighteenth century. It is argued that a company or a municipality has to first see itself as a system, not an assemblage of components. Only from that perspective can technologies be applied that simultaneously save money while reducing environmental impacts. But it is difficult to place a value on natural resources, which is what is suggested. One way proposed would be to have tax shifts that provide positive incentives to use fewer resources by reducing waste. In this context, waste is energy, raw materials and labour that goes into a process that is not embedded in the end product of the process.

Imposing economic instruments without regard for potentially damaging effects on energy intensive industries, has created a high risk of irreversible damage to the UK's manufacturing base at a time when it is already officially in recession. The government and its agencies may have to consider alternative strategies for its climate change programme and carbon reduction policies. There should be an early review of the CCL scheme to expose weaknesses. If changes are found to be desirable, timing will be critical a) to avoid serious damage to energy intensive industries and b) not lose time for revised measures to be effective before the target dates.

The scope of the detailed study for this work was limited to the energy intensive sector of manufacturing. However, the brief look at other sectors of the economy (see Section 5.3.1) puts the findings into context and serves to emphasize some of the inequities that may result from the government's present strategy. It also upholds the warnings of irreversible changes to the economy that could result from the negative economic impacts on energy intensive industries.

Since 1990, the electricity generating industry has made a large contribution to the UK's carbon emissions reduction. Although the industry is expected to do more, most energy efficiency improvements at the supply end have already been exploited. Closure of nuclear generating stations will offset the benefit of new renewable energy sources. Therefore, if the scope for further carbon savings by the electricity industry is limited, future energy efficiency improvements can now only come from end users.

Energy use by the transport and domestic sectors is expected to rise during the decade. Although the government has plans for an integrated transport strategy, it expects road transport to increase. Increased traffic volume could offset the energy and emissions savings achieved from improved vehicle efficiency.

Smaller family units and single person accommodation has increased the need for more housing. New housing stock, albeit more energy efficient than older dwellings will increase energy demand, and lower occupancy levels will lead to increased energy use per capita.

The rise in transport and domestic energy use could mean that the reduction burden could fall unfairly on the manufacturing sector of business. Absolute energy reduction targets such as that accepted by the steel industry could be met simply by reducing output and partial closure of production facilities. Site specific targets may be met by companies closing less energy efficient equipment and downsizing plant capacity rather than invest in new technologies. Both of these scenarios contribute to CO_2 emissions reduction – but to the long-term detriment of energy intensive industries and the myriad of small engineering companies that support them.

Initiatives aimed at reducing business energy use are unlikely to meet their objectives without an integrated strategy. It is arguable that the design of the existing climate change levy on energy used by business is equitable or that it will meet the expected emissions reduction without damaging energy intensive industries. This thesis offers a revised approach to the government's strategy – an approach that will encourage more efficient use of energy by UK business without impairing international competitiveness, without impeding industrial development, and without imposing significant administrative burdens. Any strategy change should be implemented as soon as possible, given that there is evidence of apathetic attitudes towards the call for reducing energy use and energy related environmental impacts.

It seems that without regulation, environmental improvement will not be given priority by business; but on the other hand, regulation or penalties to re-enforce environmental policies could be met with a negative response. A structured educational programme aimed at business with increasing emphasis on environmental issues may be one approach that could be developed by DEFRA – after all, education is a prerequisite for understanding principles, and application of acquired knowledge. An explicit plan is needed for the business sector, indicating carbon reduction contributions needed from each sector, sub-sectors and even individual enterprises. This would increase awareness of the public at large as well as industry, of the value of individual contributions towards achieving the government's targets.

The government is on the right track but needs co-operation from all quarters. There is a choice to do so – but people should behave in a responsible manner for the sake of future generations. Today's generations have the knowledge, the technology, and the means – only the *will* to apply them is needed.

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Appendices

Appendix I Questionnaire from PG Ramsell

Section A - Your foundry

1. Which casting processes are used in your foundry?

Gravity die	High pressure	Low pressure	Sand	Mixed
[ ]	[ ]	[ ]	[ ]	[ ]

2. If you have ticked 'mixed' for question 1, which is your principal casting process?

Gravity die	High pressure	Low pressure	Sand
[ ]	[ ]	[ ]	[ ]

3. Which metal alloys do you cast?

Aluminium	Zinc	Magnesium	Copper
[ ]	[ ]	[ ]	[ ]

4. If your have ticked more than one alloy, which is your predominant one?

Aluminium	Zinc	Magnesium	Copper
[ ]	[ ]	[ ]	[ ]

5. Referring to your response to Question 4, what is your approximate monthly output?

Tonnes	0-50	51-100	101-150	>150
	[ ]	[ ]	[ ]	[ ]

Please indicate if your figure is: as cast [ ] trimmed [ ] fully machined [ ]

6. Which fuel/s do you use for **melting**?

Natural gas	Electricity	Oil	LPG
[ ]	[ ]	[ ]	[ ]

7. If you use more than one fuel for **melting only**, which is the principal one?

Natural gas	Electricity	Oil	LPG
[ ]	[ ]	[ ]	[ ]

8. Which fuel/s do you use for **holding**?

Natural gas	Electricity	Oil	LPG
[ ]	[ ]	[ ]	[ ]

9. If you use more than one fuel for **holding only**, which is the principal one?

Natural gas	Electricity	Oil	LPG
[ ]	[ ]	[ ]	[ ]

Section B - Your business

10. How many employees do you have in your organisation?

< 20	20-50	51 -100	101 - 250	>250
[ ]	[ ]	[ ]	[ ]	[ ]

11. How would you describe the location and neighbourhood of your foundry?

Urban industrial	Urban mixed	Urban residential	Semi-rural	Rural
[ ]	[ ]	[ ]	[ ]	[ ]

12. Which of the following markets do you supply?

Automotive	White goods	Electrical	Engineering
[ ]	[ ]	[ ]	[ ]

13. Which is your principal market?

Automotive	White goods	Electrical	Engineering
[ ]	[ ]	[ ]	[ ]

14. If you supply the automotive industry, which of the following do you supply?

Ford	General Motors	Honda	Nissan
[ ]	[ ]	[ ]	[ ]
Rover	Toyota	Others	
[ ]	[ ]	[ ]	

15. Do you export to the following regions?

Continental Europe	North America	Other
[ ]	[ ]	[ ]

16. Is your company a member of any of the following trade organisations?

BFA	BMCA	BICTA	CDC	CBI
[ ]	[ ]	[ ]	[ ]	[ ]
Diecasting Society	EEF	Other		
[ ]	[ ]	[ ]		

17. Are you or your colleagues members of the Institute of British Foundrymen?

Yes [ ]   No [ ]

Section C - Environmental management

18. Do your major customers encourage environmental management?

Yes - all [ ]   Yes - some [ ]   No [ ]

19. Do you have a certified QA system?

Yes [ ]   No [ ]

20. Do you have an Environmental Management System (EMS)?

Yes [ ]   No [ ]

21. Do you have ISO14001 certification?

Yes [ ]   No [ ]

22. If you do not have ISO14001, are you working towards certification?

Yes [ ]   No [ ]

Section D - Energy efficiency

23. Is there an energy manager in your organisation?

Yes [ ]   No [ ]

24. How would you rate the energy efficiency of your metal melting equipment?

High [ ]   Average [ ]   Low [ ]

25. Do you consider that you could improve the energy efficiency of your metal melting and holding operations?

Yes [ ]   No [ ]   Not sure [ ]

26. If you answered 'yes' to question 25, which of the following actions would be required?

Minor changes	Major changes	Better planning	New furnaces	Changing fuels
[ ]	[ ]	[ ]	[ ]	[ ]

Section E - Environmental issues

27. Are you aware of the threat of enhanced global warming and climate change?

Yes	No
[ ]	[ ]

28. Are you aware of the EU and UK commitments to reducing GHG emissions particularly CO_2?

Yes	No
[ ]	[ ]

29. Do you think that your company could make a meaningful contribution to the Government's commitment to reducing CO_2 emissions?

Yes	No
[ ]	[ ]

30. If you answered 'yes' to question 29, do you have plans to do so?

Yes	No
[ ]	[ ]

31. Are you aware of the proposed Climate Change Levy (energy tax)?

Yes	No
[ ]	[ ]

32. In your opinion, have past government sponsored initiatives to encourage industry to improve energy efficiency been successful?

Yes	No	Don't know
[ ]	[ ]	[ ]

33. How would you compare your company's energy prices with foreign competitors?

Higher	Lower	Similar
[ ]	[ ]	[ ]

34. How will your company respond to the financial impact of the levy?

Don't know [ ]	Improve efficiency [ ]	Lower energy prices [ ]
Change fuels [ ]	Change suppliers [ ]	Raise sales prices [ ]

35. Do you consider that higher energy prices and/or energy tax will encourage energy efficiency projects;

a) in your organisation? Yes [ ] No [ ]

b) in industry generally? Yes [ ] No [ ]

36. Are you aware of the Government's deliberations on 'tradable' emissions permits?

Yes [ ] No [ ]

37. Are you aware of the proposals for an 'emissions trading' scheme?

Yes [ ] No [ ]

38. Do you understand the mechanism of a trading scheme?

Yes [ ] No [ ]

39. Please give any brief comments you may have relevant to the questions in Section E of this questionnaire; eg impacts on UK industrial competitiveness, cast metals sector, your company, etc.

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Appendix II

Summary of the Climate Change Levy Negotiated Energy Agreement (NEA) related to foundries.

- The Climate Change Levy NEA will be implemented throughout the UK with effect from 1 April 2001.
- Levy rates of 0.43p/kWh will be applied to electricity and 0.15p/kWh to gas by energy suppliers.
- A discount of 80% is available to all UK casting producers on the levy applied to gas and electricity consumed by eligible casting processes.
- Eligible casting processes are those covered by the European Commission IPPC (Integrated Pollution Prevention & Control) Directive enacted in the UK in the Pollution Prevention and Control (PPC) Regulations 2000 and those processes deemed by DETR to be technically linked.
- In return for the rebate companies must commit reduce their energy consumption by undertaking all the changes in working practices and capital investments which have a payback of two years or less.
- Companies must also implement appropriate energy management systems and sub-metering where these are absent. However the scope and complexity of these elements of agreement need only reflect the size and complexity of the foundry in question.
- Where 90% or more of a site's total energy consumption is used by IPPC (PPC) regulated processes then the whole of the electricity and gas consumption for the site is eligible for the rebate.
- Where less than 90% of a site's total energy consumption is used by IPPC (PPC) regulated processes only the actual amount of electricity and gas consumed by such processes is eligible for the rebate.
- Coke used for dual purposes in the manufacture of iron castings is currently exempt from the levy.

- The sector's energy reduction target or 11% was the aggregated ACE energy savings identified by a series of independent energy audits commission by all IPPC affected foundries wishing to join the NEA.
- Non-IPPC affected companies may adopt the sector target for the duration of the agreement or convert to a site specific target by commissioning an independent energy audit at any time up to July 2002.
- Participating companies will report their progress through Target 2010.

Appendix III

Annual costs of energy efficiency improvement measures for host foundries

Foundry A

(Existing levies - Allowance for NI reduction)

Phase 1	No cost measures only		£ 0
	NI reduction (100 employees @ £17k x 0.003%)		- £ 5100
		Use	**- £ 5100**
Phase 2	Install covers on electric holding furnaces, 10@£360		£ 3600
	Twice yearly combustion checks @ £480		£ 960
	Energy management		£ 1000
		Total	£ 5560
	NI reduction (100 employees @ £15k x 0.003%)		-£ 5100
		Use	**£ 500**
Phase 3 Yr 1	Convert melting furnaces to rear flue and fit covers 3 x £2400		£ 7200
	Sub-metering, 5 cells @ £1600		£ 8000
	Combustion checks		£ 960
	Energy management system		£ 3000
		Total	£19160
	NI reduction (100 employees @ £15k x 0.003%)		-£ 5100
		Use	**£14000**
Phase 3 Yr 2	Combustion checks		£ 960
	Energy management system		£ 3000
		Total	£ 3960
	NI reduction (100 employees @ £15k x 0.003%)		-£ 5100
		Use	**- £ 1000**
Phase 3 Yr 3	Combustion checks		£ 960
	Energy management system		£ 3000
		Total	£ 3960
	NI reduction (100 employees @ £15k x 0.003%)		-£ 5100
		Use	**- £ 1000**
Phase 4 Yr 1	Combustion checks		£ 960
	Energy management system		£ 3500
		Total	£ 4460
	NI reduction (100 employees @ £15k x 0.003%)		-£ 5100
		Use	**- £ 500**
Phase 4 Yr 2	Combustion checks		£ 960
	Energy management system		£ 3500
		Total	£ 4460
	NI reduction (100 employees @ £15k x 0.003%)		-£ 5100
		Use	**- £ 500**
Phase 4 Yr 3	Combustion checks		£ 960
	Energy management system		£ 3500
		Total	£ 4460
	NI reduction (100 employees @ £15k x 0.003%)		-£ 5100
		Use	**- £ 500**
Phase 4 Yr 4	Combustion checks		£ 960
	Energy management system		£ 3500
		Total	£ 4460
	NI reduction (100 employees @ £15k x 0.003%)		-£ 5100
		Use	**- £ 500**

Foundry A

(Incremental levies – no NI reduction)

Phase 1	No cost measures only		£ 0
		Use	**£ 0**
Phase 2	Install covers on electric holding furnaces, 10@£360		£ 3600
	Twice yearly combustion checks @ £480		£ 960
	Energy management		£ 1000
		Total	£ 5560
		Use	**£ 6000**
Phase 3 Yr 1	Convert melting furnaces to rear flue and fit covers 3 x £2400		£ 7200
	Sub-metering, 5 cells @ £1600		£ 8000
	Combustion checks		£ 960
	Energy management system		£ 3000
		Total	£19161
		Use	**£19000**
Phase 3 Yr 2	Combustion checks		£ 960
	Energy management system		£ 3000
		Total	£ 3960
		Use	**£ 4000**
Phase 3 Yr 3	Combustion checks		£ 960
	Energy management system		£ 3000
		Total	£ 3960
		Use	**£ 4000**
Phase 4 Yr 1	Combustion checks		£ 960
	Energy management system		£ 3500
		Total	£ 4460
		Use	**£ 4500**
Phase 4 Yr 2	Combustion checks		£ 960
	Energy management system		£ 3500
		Total	£ 4460
		Use	**£ 4500**
Phase 4 Yr 3	Combustion checks		£ 960
	Energy management system		£ 3500
		Total	£ 4460
		Use	**£ 4500**
Phase 4 Yr 4	Combustion checks		£ 960
	Energy management system		£ 3500
		Total	£ 4460
		Use	**£ 4500**

Foundry B

(Existing levies - Allowance for NI reduction)

Phase 1	No cost measures only		£ 0
	Energy management		£ 6000
	2010 fee		£ 750
		Total	£ 6750
	NI reduction (200 employees @ £17k x 0.003)		£10200
		Use	**- £ 3500**
Phase 2	Install covers on melting furnaces, 4@£800		£ 3200
	Twice yearly combustion checks @ £480		£ 960
	Energy management		£ 6000
	2010 & Audit fees (BMCA estimate)		£ 4250
		Total	£14410
	NI reduction (200 employees @ £15k x 0.003)		£10200
		Use	**£ 4000**
Phase 3 Yr 1	Install sub-metering		£ 6000
	Combustion checks		£ 960
	Energy management system		£ 6000
	Modify tooling		£ 5000
	2010 & Audit fees		£ 4250
		Total	£22210
	NI reduction (200 employees @ £15k x 0.003)		£10200
		Use	**£12000**
Phase 3 Yr 2	Combustion checks		£ 960
	Energy management system		£ 6000
	Modify tooling		£ 5000
	2010 & Audit fees		£ 4250
		Total	£17210
	NI reduction (200 employees @ £15k x 0.003)		£10200
		Use	**£ 7000**
Phase 3 Yr 3	Combustion checks		£ 960
	Energy management system		£ 6000
	Modify tooling		£ 5000
	2010 & Audit fees		£ 4250
		Total	£17210
	NI reduction (200 employees @ £15k x 0.003)		£10200
		Use	**£ 7000**
Phase 4 Yr 1	Combustion monitoring		£ 960
	Energy management system		£ 6000
	2010 & Audit fees		£ 4250
		Total	£11210
	NI reduction (200 employees @ £15k x 0.003)		£10200
		Use	**£ 1000**
Phase 4 Yr 2	Combustion monitoring		£ 960
	Energy management system		£ 6000
	2010 & Audit fees		£ 4250
		Total	£11210
	NI reduction (200 employees @ £15k x 0.003)		£10200
		Use	**£ 1000**
Phase 4 Yr 3	Combustion monitoring		£ 960
	Energy management system		£ 6000
	2010 & Audit fees		£ 4250
		Total	£11210
	NI reduction (200 employees @ £15k x 0.003)		£10200
		Use	**£ 1000**
Phase 4 Yr 4	Combustion monitoring		£ 960
	Energy management system		£ 6000
	2010 & Audit fees		£ 4250
		Total	£11210
	NI reduction (200 employees @ £15k x 0.003)		£10200
		Use	**£ 1000**

Foundry B

(Incremental levies – no NI reduction)

Phase 1	No cost measures only		£ 0
	Energy management		£ 6000
		Total	£ 6000
		Use	**£ 6000**
Phase 2	Install covers on melting furnaces, 4@£800		£ 3200
	Twice yearly combustion checks @ £480		£ 960
	Energy management		£ 6000
		Total	£10160
		Use	**£10000**
Phase 3 Yr 1	Install sub-metering		£ 6000
	Combustion checks		£ 960
	Energy management system		£ 6000
	Modify tooling		£ 5000
		Total	£17960
		Use	**£18000**
Phase 3 Yr 2	Combustion checks		£ 960
	Energy management system		£ 6000
	Modify tooling		£ 5000
		Total	£11960
		Use	**£12000**
Phase 3 Yr 3	Combustion checks		£ 960
	Energy management system		£ 6000
	Modify tooling		£ 5000
		Total	£11960
		Use	**£12000**
Phase 4 Yr 1	Combustion monitoring		£ 960
	Energy management system		£ 6000
		Total	£ 6960
		Use	**£ 7000**
Phase 4 Yr 2	Combustion monitoring		£ 960
	Energy management system		£ 6000
		Total	£ 6960
		Use	**£ 7000**
Phase 4 Yr 3	Combustion monitoring		£ 960
	Energy management system		£ 6000
		Total	£ 6960
		Use	**£ 7000**
Phase 4 Yr 4	Combustion monitoring		£ 960
	Energy management system		£ 6000
		Total	£ 6960
		Use	**£ 7000**

Foundry C

(Existing levies - Allowance for NI reduction)

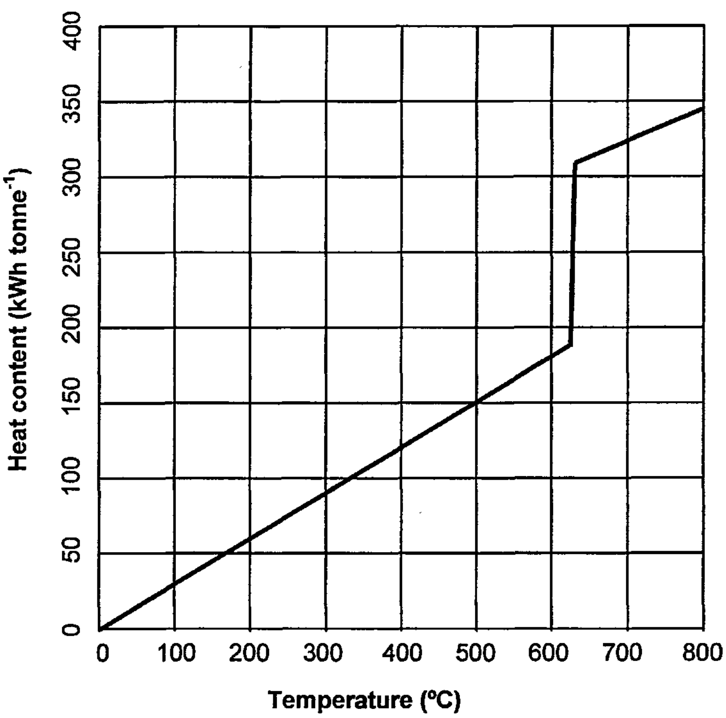
Phase 1	No cost measures only		£ 0
	Energy management		£ 6000
	2010 fee		£ 750
		Total	£ 6750
	NI reduction (200 employees @ £15k x 0.003%)		£ 9000
		Use	**- £ 2250**
Phase 2	Twice yearly combustion checks @ £480		£ 960
	Energy management		£10000
	2010 & Audit fees		£ 4250
		Total	£15210
	NI reduction (200 employees @ £15k x 0.003%)		£ 9000
		Use	**£ 6000**
Phase 3 Yr 1	Install sub-metering		£ 6000
	Combustion checks		£ 960
	Energy management system		£10000
	2010 & Audit fees		£ 4250
	Modify tooling		£ 6000
		Total	£27210
	NI reduction (200 employees @ £15k x 0.003%)		£ 9000
		Use	**£18000**
Phase 3 Yr 2	Combustion checks		£ 960
	Energy management system		£10000
	2010 & Audit fees		£ 4250
	Modify tooling		£12000
		Total	£27210
	NI reduction (200 employees @ £15k x 0.003%)		£ 9000
		Use	**£18000**
Phase 3 Yr 3	Combustion checks		£ 960
	Energy management system		£10000
	2010 & Audit fees		£ 4250
	Modify tooling		£12000
		Total	£27210
	NI reduction (200 employees @ £15k x 0.003%)		£ 9000
		Use	**£18000**
Phase 4 Yr 1	Combustion monitoring		£ 960
	Energy management system		£10000
	2010 & Audit fees		£ 4250
		Total	£15210
	NI reduction (200 employees @ £15k x 0.003%)		£ 9000
		Use	**£ 6000**
Phase 4 Yr 2	Combustion monitoring		£ 960
	Energy management system		£10000
	2010 & Audit fees		£ 4250
		Total	£15210
	NI reduction (200 employees @ £15k x 0.003%)		£ 9000
		Use	**£ 6000**
Phase 4 Yr 3	Combustion monitoring		£ 960
	Energy management system		£10000
	2010 & Audit fees		£ 4250
		Total	£15210
	NI reduction (200 employees @ £15k x 0.003%)		£ 9000
		Use	**£ 6000**
Phase 4 Yr 4	Combustion monitoring		£ 960
	Energy management system		£10000
	2010 & Audit fees		£ 4250
		Total	£15210
	NI reduction (200 employees @ £15k x 0.003%)		£ 9000
		Use	**£ 6000**

Foundry C

(Incremental levies – no NI reduction)

Phase 1	No cost measures only		£ 0
	Energy management		£ 6000
		Total	£ 6000
		Use	**£ 6000**
Phase 2	Twice yearly combustion checks @ £480		£ 960
	Energy management		£10000
		Total	£10960
		Use	**£11000**
Phase 3 Yr 1	Install sub-metering		£ 6000
	Combustion checks		£ 960
	Energy management system		£10000
	Modify tooling		£ 6000
		Total	£22960
		Use	**£23000**
Phase 3 Yr 2	Combustion checks		£ 960
	Energy management system		£10000
	Modify tooling		£12000
		Use	**£23000**
Phase 3 Yr 3	Combustion checks		£ 960
	Energy management system		£10000
	Modify tooling		£12000
		Total	£22960
		Use	**£23000**
Phase 4 Yr 1	Combustion monitoring		£ 960
	Energy management system		£10000
		Total	£10960
		Use	**£11000**
Phase 4 Yr 2	Combustion monitoring		£ 960
	Energy management system		£10000
		Total	£10960
		Use	**£11000**
Phase 4 Yr 3	Combustion monitoring		£ 960
	Energy management system		£10000
		Total	£10960
		Use	**£11000**
Phase 4 Yr 4	Combustion monitoring		£ 960
	Energy management system		£10000
		Total	£10960
		Use	**£11000**

Appendix IV ***Heat content graph for aluminium (above 0°C).***



Heat content graph for aiuminium (above 0°C)

Source: Electrotechnology Technical Handbook – Midlands Electricity Board

Appendix V *Tables of experiments using spreadsheet model. (6 pages)*

Experiments – Postulation 1 - 4 Phases - Existing levy - mitigated costs - 0.3% NI reduction (*Cost of measures as Appendix III p. 1)

Foundry A

	Year 0	Phase 1	Phase 2	Phase 3			Phase 4				
		2002	2003	2004	2005	2006	2007	2008	2009	2010	
Levy on electricity (£ kWh^{-1})		0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	
Levy on gas (£ kWh^{-1})		0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	
Electricity price (£ kWh^{-1})	0.0318	0.0318	0.0318	0.0318	0.0318	0.0318	0.0318	0.0318	0.0318	0.0318	
Gas price (£ kWh^{-1})	0.0109	0.0109	0.0109	0.0109	0.0109	0.0109	0.0109	0.0109	0.0109	0.0109	
Total gross energy cost (£ $annum^{-1}$)	334050	334050	334050	334050	334050	334050	334050	334050	334050	334050	
Cost of reduction measures (£ $annum^{-1}$)*		-5100	500	14000	-1000	-1000	-500	-500	-500	-500	0.3%
Total energy cost incl. levies		339150	333550	320050	335050	335050	334550	334550	334550	334550	
Electricity use (kWh $annum^{-1}$)	6338975	5636842	5543767	5319391	5568698	5568698	5560388	5560388	5560388	5560388	
Electricity cost (£ $annum^{-1}$)	201579	179252	176292	169157	177085	177085	176820	176820	176820	176820	
Electricity levy (£)	0	24238	23838	22873	23945	23945	23910	23910	23910	23910	
Total electricity cost (£ $annum^{-1}$)	201579	203490	200130	192030	201030	201030	200730	200730	200730	200730	
Gas cost (£ $annum^{-1}$)	132471	119250	119153	109720	114863	114863	114691	114691	114691	114691	
Gas levy (£)	0	16410	16397	15099	15807	15807	15783	15783	15783	15783	
Total gas cost (£)	132471	135660	130085	124820	130670	130670	130475	130475	130475	130475	
Electricity use (kWh_p $annum^{-1}$)	16481335	14655789	14413795	13830416	14478615	14478615	14457008	14457008	14457008	14457008	
Saving to neutralize		11.1%	12.5%	16.1%	12.2%	12.2%	12.3%	12.3%	12.3%	12.3%	
Gas use (kWh $annum^{-1}$)	12153280	10940323	10931471	10066089	10537863	10537863	10522137	10522137	10522137	10522137	
Saving to neutralize		10.0%	10.1%	17.2%	13.3%	13.3%	13.4%	13.4%	13.4%	13.4%	
Total primary energy use (kWh $annum^{-1}$)	28634615	25596112	25345266	23896504	25016478	25016478	24979145	24979145	24979145	24979145	
Electricity use reduction (kWh_p $annum^{-1}$)		1825546	2067540	2650919	2002720	2002720	2024327	2024327	2024327	2024327	
Gas use reduction (kWh $annum^{-1}$)		1212957	1221809	2087191	1615417	1615417	1631143	1631143	1631143	1631143	
Reduction in primary energy use (kWh_p)		3038503	3289349	4738111	3618137	3618137	3655470	3655470	3655470	3655470	**12.8%**
Total levy (£ $annum^{-1}$)		40649	40235	37973	39752	39752	39693	39693	39693	39693	
Total net energy cost (£ $annum^{-1}$)		298501	295445	278877	291947	291947	291512	291512	291512	291512	

Experiments – Postulation 2 - 4 Phases - Incremental levy - no NI reduction (*Cost of measures as Appendix III p. 2)

Foundry A

	Year 0	Phase 1	Phase 2		Phase 3		Phase 4				
		2002	2003	2004	2005	2006	2007	2008	2009	2010	
Levy on electricity (£ kWh^{-1})		0.0010	0.0020	0.0030	0.0030	0.0030	0.0043	0.0043	0.0043	0.0043	
Levy on gas (£ kWh^{-1})		0.0003	0.0006	0.0011	0.0011	0.0011	0.0015	0.0015	0.0015	0.0015	
Electricity price (£ kWh^{-1})	0.0318	0.0318	0.0318	0.0318	0.0318	0.0318	0.0318	0.0318	0.0318	0.0318	
Gas price (£ kWh^{-1})	0.0109	0.0109	0.0109	0.0109	0.0109	0.0109	0.0109	0.0109	0.0109	0.0109	
Total gross energy cost (£ $annum^{-1}$)	334050	334050	334050	334050	334050	334050	334050	334050	334050	334050	
Cost of reduction measures (£ $annum^{-1}$)*		0	6000	19000	4000	4000	4500	4500	4500	4500	1.7%
Total energy cost incl. levies		334050	328050	315050	330050	330050	329550	329550	329550	329550	
Electricity use (kWh $annum^{-1}$)	6338975	6110671	5823373	5431897	5690517	5690517	5477285	5477285	5477285	5477285	
Electricity cost (£ $annum^{-1}$)	201579	194319	185183	172734	180958	180958	174178	174178	174178	174178	
Electricity levy (£)	0	6111	11647	16296	17072	17072	23552	23552	23552	23552	
Total electricity cost (£ $annum^{-1}$)	201579	200430	196830	189030	198030	198030	197730	197730	197730	197730	
Gas cost (£ $annum^{-1}$)	132471	130041	117188	111606	116920	116920	112977	112977	112977	112977	
Gas levy (£)	0	3579	6451	11263	11799	11799	15547	15547	15547	15547	
Total gas cost (£)	132471	133620	127940	122870	128720	128720	128525	128525	128525	128525	
Electricity use (kWh_p $annum^{-1}$)	16481335	15887744	15140769	14122931	14795345	14795345	14240942	14240942	14240942	14240942	
Saving to neutralize		3.6%	8.1%	14.3%	10.2%	10.2%	13.6%	13.6%	13.6%	13.6%	
Gas use (kWh)	12153280	11930357	10751218	10239125	10726625	10726625	10364879	10364879	10364879	10364879	
Saving to neutralize		1.8%	11.5%	15.8%	11.7%	11.7%	14.7%	14.7%	14.7%	14.7%	
Total primary energy use (kWh_p)	28634615	27818101	25891988	24362056	25521970	25521970	24605821	24605821	24605821	24605821	
Electricity use reduction (kWh_p $annum^{-1}$)		593591	1340566	2358404	1685990	1685990	2240393	2240393	2240393	2240393	
Gas use reduction (kWh $annum^{-1}$)		222923	1402062	1914155	1426655	1426655	1788401	1788401	1788401	1788401	
Reduction in primary energy use (kWh_p)		816514	2742627	4272559	3112645	3112645	4028794	4028794	4028794	4028794	**14.1%**
Total levy (£ $annum^{-1}$)		9690	18097	27559	28871	28871	39100	39100	39100	39100	
Total net energy cost (£ $annum^{-1}$)		324360	302372	284341	297879	297879	287155	287155	287155	287155	

Experiments – Postulation 1 - 4 Phases - Existing levy - 80% discount – mitigated costs - 0.3% NI reduction (*Cost of measures as Appendix III p. 3)

Foundry B

	Year 0	Phase 1	Phase 2	Phase 3			Phase 4				
		2002	2003	2004	2005	2006	2007	2008	2009	2010	
Levy on electricity (£ kWh^{-1})		0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	
Levy on gas (£ kWh^{-1})		0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	
Electricity price (£ kWh^{-1})	0.0296	0.0296	0.0296	0.0296	0.0296	0.0296	0.0296	0.0296	0.0296	0.0296	
Gas price (£ kWh^{-1})	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	
Total gross energy cost (£ $annum^{-1}$)	277423	277423	277423	277423	277423	277423	277423	277423	277423	277423	
Cost of reduction measures (£ $annum^{-1}$)*		-3500	4000	12000	7000	7000	1000	1000	1000	1000	1.4%
Total energy cost incl. levies		280923	273423	265423	270423	270423	276423	276423	276423	276423	
Electricity use (kWh $annum^{-1}$)	4897767	4795796	4667760	4531187	4616545	4616545	4718974	4718974	4718974	4718974	
Electricity cost (£ $annum^{-1}$)	144974	141956	138166	134123	136650	136650	139682	139682	139682	139682	
Electricity levy (£)	0	4124	4014	3897	3970	3970	4058	4058	4058	4058	
Total electricity cost (£ $annum^{-1}$)	144974	162577	158237	153607	156501	156501	159973	159973	159973	159973	
Gas cost (£ $annum^{-1}$)	132450	130798	127306	123581	125909	125909	128703	128703	128703	128703	
Gas levy (£)	0	4045	3937	3822	3894	3894	3980	3980	3980	3980	
Total gas cost (£)	132450	151024	106635	103515	105465	105465	107805	107805	107805	107805	
Electricity use (kWh_p $annum^{-1}$)	12734194	12469071	12136175	11781087	12003017	12003017	12269333	12269333	12269333	12269333	
Saving to neutralize		2.1%	4.7%	7.5%	5.7%	5.7%	3.7%	3.7%	3.7%	3.7%	
Gas use (kWh)	13654597	13484304	13124304	12740304	12980304	12980304	13268304	13268304	13268304	13268304	
Saving to neutralize		1.2%	3.9%	6.7%	4.9%	4.9%	2.8%	2.8%	2.8%	2.8%	
Total primary energy use (kWh_p)	26388791	25953375	25260479	24521391	24983321	24983321	25537637	25537637	25537637	25537637	**3.2%**
Electricity use reduction (kWh_p $annum^{-1}$)		265123	598019	953108	731177	731177	464861	464861	464861	464861	
Gas use reduction (kWh $annum^{-1}$)		170293	530293	914293	674293	674293	386293	386293	386293	386293	
Total levy (£ $annum^{-1}$)		8170	7952	7719	7864	7864	8039	8039	8039	8039	
Total net energy cost (£ $annum^{-1}$)		272753	265471	257704	262559	262559	268384	268384	268384	268384	

Experiments – Postulation 2 - 4 Phases - Incremental levy - no NI reduction (*Cost of measures as Appendix III p. 4)

Foundry B

	Year 0	Phase 1	Phase 2	Phase 3			Phase 4				
		2002	2003	2004	2005	2006	2007	2008	2009	2010	
Levy on electricity (£ kWh^{-1})		0.0010	0.0020	0.0030	0.0030	0.0030	0.0043	0.0043	0.0043	0.0043	
Levy on gas (£ kWh^{-1})		0.0003	0.0006	0.0011	0.0011	0.0011	0.0015	0.0015	0.0015	0.0015	
Electricity price (£ kWh^{-1})	0.0296	0.0296	0.0296	0.0296	0.0296	0.0296	0.0296	0.0296	0.0296	0.0296	
Gas price (£ kWh^{-1})	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	0.0097	
Total gross energy cost (£ $annum^{-1}$)	277423	277423	277423	277423	277423	277423	277423	277423	277423	277423	
Cost of reduction measures (£ $annum^{-1}$)*		6000	10000	18000	12000	12000	7000	7000	7000	7000	3.2%
Total energy cost incl. levies		271423	267423	259423	265423	265423	270423	270423	270423	270423	
Electricity use (kWh $annum^{-1}$)	4897767	4612417	4400632	4138036	4233741	4233741	4148081	4148081	4148081	4148081	
Electricity cost (£ $annum^{-1}$)	144974	136528	130259	122486	125319	125319	122783	122783	122783	122783	
Electricity levy (£)	0	4612	8801	12414	12701	12701	17837	17837	17837	17837	
Total electricity cost (£ $annum^{-1}$)	144974	141140	139060	134900	138020	138020	140620	140620	140620	140620	
Gas cost (£ $annum^{-1}$)	132450	126375	120886	111840	114427	114427	112419	112419	112419	112419	
Gas levy (£)	0	3908	7477	12683	12976	12976	17384	17384	17384	17384	
Total gas cost (£)	132450	130283	104295	101175	103515	103515	105465	105465	105465	105465	
Electricity use (kWh_p $annum^{-1}$)	12734194	11992284	11441642	10758893	11007727	11007727	10785012	10785012	10785012	10785012	
Saving to neutralize		5.8%	10.2%	15.5%	13.6%	13.6%	15.3%	15.3%	15.3%	15.3%	
Gas use (kWh)	13654597	13028304	12462431	11529911	11796578	11796578	11589557	11589557	11589557	11589557	
Saving to neutralize		4.6%	8.7%	15.6%	13.6%	13.6%	15.1%	15.1%	15.1%	15.1%	
Total primary energy use (kWh_p)	26388791	25020588	23904073	22288804	22804305	22804305	22374569	22374569	22374569	22374569	**15.2%**
Electricity use reduction (kWh_p $annum^{-1}$)		741910	1292552	1975302	1726467	1726467	1949183	1949183	1949183	1949183	
Gas use reduction (kWh $annum^{-1}$)		626293	1192166	2124686	1858019	1858019	2065040	2065040	2065040	2065040	
Total levy (£ $annum^{-1}$)		8521	16279	25097	25677	25677	35221	35221	35221	35221	
Total net energy cost (£ $annum^{-1}$)		262902	251144	234326	239746	239746	235202	235202	235202	235202	

Experiments - Postulation 1 - 4 Phases - Existing levy - 80% discount – mitigated costs - 0.3% NI reduction (*Cost of measures as Appendix III p. 5)

Foundry C

	Year 0	Phase 1	Phase 2	Phase 3			Phase 4				
		2002	2003	2004	2005	2006	2007	2008	2009	2010	
Levy on electricity (£ kWh^{-1})		0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	0.0043	
Levy on gas (£ kWh^{-1})		0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	
Electricity price (£ kWh^{-1})	0.0327	0.0327	0.0327	0.0327	0.0327	0.0327	0.0327	0.0327	0.0327	0.0327	
Gas price (£ kWh^{-1})	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	
Total gross energy cost (£ $annum^{-1}$)	472565	472565	472565	472565	472565	472565	472565	472565	472565	472565	
Cost of reduction measures (£ $annum^{-1}$)*		-2250	6000	18000	18000	18000	6000	6000	6000	6000	2.0%
Total energy cost incl. levies		474815	466565	454565	454565	454565	466565	466565	466565	466565	
Electricity use (kWh $annum^{-1}$)	10737408	10512144	10329493	10063820	10063820	10063820	10329493	10329493	10329493	10329493	
Electricity cost (£ $annum^{-1}$)	351113	343747	337774	329087	329087	329087	337774	337774	337774	337774	
Electricity levy (£)	0	9040	8883	8655	8655	8655	8883	8883	8883	8883	
Total electricity cost (£ $annum^{-1}$)	351113	388949	382191	372361	372361	372361	382191	382191	382191	382191	
Gas cost (£ $annum^{-1}$)	121452	118669	116607	113608	113608	113608	116607	116607	116607	116607	
Gas levy (£)	0	3359	3300	3215	3215	3215	3300	3300	3300	3300	
Total gas cost (£)	121452		181960	177280	177280	177280	181960	181960	181960	181960	
Electricity use (kWh_p $annum^{-1}$)	27917261	27331574	26856683	26165932	26165932	26165932	26856683	26856683	26856683	26856683	
Saving to neutralize		2.1%	3.8%	6.3%	6.3%	6.3%	3.8%	3.8%	3.8%	3.8%	
Gas use (kWh $annum^{-1}$)	11457727	11195179	11000661	10717725	10717725	10717725	11000661	11000661	11000661	11000661	
Saving to neutralize		2.3%	4.0%	6.5%	6.5%	6.5%	4.0%	4.0%	4.0%	4.0%	
Total primary energy use (kWh_p)	39374988	38526753	37857344	36883657	36883657	36883657	37857344	37857344	37857344	37857344	
Electricity use reduction (kWh_p $annum^{-1}$)		585687	1060578	1751329	1751329	1751329	1060578	1060578	1060578	1060578	
Gas use reduction (kWh $annum^{-1}$)		262548	457066	740002	740002	740002	457066	457066	457066	457066	
Reduction in primary energy use (kWh_p)		848235	1517644	2491331	2491331	2491331	1517644	1517644	1517644	1517644	**3.9%**
Total levy (£ $annum^{-1}$)		12399	12184	11870	11870	11870	12184	12184	12184	12184	
Total net energy cost (£ $annum^{-1}$)		462416	454381	442695	442695	442695	454381	454381	454381	454381	

Experiments - Postulation 2 - 4 Phases - Incremental levy – no NI reduction (*Cost of measures as Appendix III p. 6)

Foundry C

	Year 0	Phase 1	Phase 2	Phase 3			Phase 4				
		2002	2003	2004	2005	2006	2007	2008	2009	2010	
Levy on electricity (£ kWh^{-1})		0.0010	0.0020	0.0030	0.0030	0.0030	0.0043	0.0043	0.0043	0.0043	
Levy on gas (£ kWh^{-1})		0.0003	0.0006	0.0011	0.0011	0.0011	0.0015	0.0015	0.0015	0.0015	
Electricity price (£ kWh^{-1})	0.0327	0.0327	0.0327	0.0327	0.0327	0.0327	0.0327	0.0327	0.0327	0.0327	
Gas price (£ kWh^{-1})	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	
Total gross energy cost (£ $annum^{-1}$)	472565	472565	472565	472565	472565	472565	472565	472565	472565	472565	
Cost of reduction measures (£ $annum^{-1}$)*		6000	11000	23000	23000	23000	11000	11000	11000	11000	2.9%
Total energy cost incl. levies		466565	461565	449565	449565	449565	461565	461565	461565	461565	
Electricity use (kWh $annum^{-1}$)	10737408	10286581	9883078	9356493	9356493	9356493	9268724	9268724	9268724	9268724	
Electricity cost (£ $annum^{-1}$)	351113	336371	323177	305957	305957	305957	303087	303087	303087	303087	
Electricity levy (£)	0	10287	19766	28069	28069	28069	39856	39856	39856	39856	
Total electricity cost (£ $annum^{-1}$)	351113	346658	342943	334027	334027	334027	342943	342943	342943	342943	
Gas cost (£ $annum^{-1}$)	121452	116607	117294	113189	113189	113189	115357	115357	115357	115357	
Gas levy (£)	0	3300	6639	11746	11746	11746	16324	16324	16324	16324	
Total gas cost (£)	121452		180010	175330	175330	175330	180010	180010	180010	180010	
Electricity use (kWh_p $annum^{-1}$)	27917261	26745112	25696002	24326881	24326881	24326881	24098683	24098683	24098683	24098683	
Saving to neutralize		4.2%	8.0%	12.9%	12.9%	12.9%	13.7%	13.7%	13.7%	13.7%	
Gas use (kWh $annum^{-1}$)	11457727	11000661	11065504	10678207	10678207	10678207	10882771	10882771	10882771	10882771	
Saving to neutralize		4.0%	3.4%	6.8%	6.8%	6.8%	5.0%	5.0%	5.0%	5.0%	
Total primary energy use (kWh_p)	39374988	37745773	36761506	35005089	35005089	35005089	34981454	34981454	34981454	34981454	
Electricity use reduction (kWh_p $annum^{-1}$)		1172149	2221259	3590379	3590379	3590379	3818578	3818578	3818578	3818578	
Gas use reduction (kWh $annum^{-1}$)		457066	392223	779520	779520	779520	574956	574956	574956	574956	
Reduction in primary energy use (kWh_p)		1629215	2613482	4369899	4369899	4369899	4393534	4393534	4393534	4393534	**11.2%**
Total levy (£ $annum^{-1}$)		13587	26405	39816	39816	39816	56180	56180	56180	56180	
Total net energy cost (£ $annum^{-1}$)		452978	440471	419146	419146	419146	418445	418445	418445	418445	

Appendix VI *Sample template for calculating site specific energy consumption.*

	Sub-process energy use (kWh tonne^{-1})			
Sub-process	**Sand casting**	**Gravity diecasting**	**High pressure d/c**	**Low pressure d/c**
Melting & holding	m_S	m_G	m_H	m_L
Trimming/fettling/de-coring	t_S	t_G	t_H	t_L
Heat treatment	h_S	h_G	h_H	h_L
Sand reclamation	r_S	r_G	r_H	r_L
Emissions control	e_S	e_G	e_H	e_L
Motive power	p_S	p_G	p_H	p_L
Site services	s_S	s_G	s_H	s_L
Process SEC *(v)*	v_S = Sum $(m_S{:}s_S)$	v_G = Sum $(m_G{:}s_G)$	v_H = Sum $(m_H{:}s_H)$	v_L = Sum $(m_L{:}s_L)$
Output *(w)* (tonnes annum^{-1})	w_S	w_G	w_H	w_L
Process energy use (kWh annum^{-1})	$v_S \times w_S$	$v_G \times w_G$	$v_H \times w_H$	$v_L \times w_L$

Total output *(w_A)* (tonnes annum^{-1}) $w_A = (w_S{:}w_L)$

Total energy use *(x)* (kWh annum^{-1}) $x = \text{Sum}\ \{(v_S \times w_S){:}(v_L \times w_L)\}$

Site specific energy consumption *(SEC_S)* (kWh tonne^{-1}) $SEC_S = x/w_A$